Appendix to the June 27, 2012 Draft Vision for Clean Air: A Framework for Air Quality and Climate Planning

Scenario Assumptions and Results

August 20, 2012

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Introduction

The Public Review Draft of *Vision for Clean Air: A Framework for Air Quality and Climate Planning* released June 27, 2012 takes a coordinated look at the challenge of meeting California's multiple air quality and climate goals. The draft Vision illustrates a process for future planning that takes into account multiple pollutants over the long-term.

Provided in this document is a description of the scenarios used in the *Vision for Clean Air* exercise. This Appendix documents the assumptions, inputs, and results of all the scenarios that were evaluated. The results formed the basis of the key concepts presented in the June 27, 2012 Public Review Draft of *Vision for Clean Air: A Framework for Air Quality and Climate Planning*.

The Vision effort is the beginning of a dialogue on how California can move forward to address its clean air goals in ways that enhance both its economy and environment. The Vision process was designed to take a broader view of clean air strategies than the traditional State Implementation Plan (SIP) process under the federal Clean Air Act. When federal SIP planning requirements are combined with California's greenhouse gas reduction program, a broader view is needed to effectively address both air quality and climate planning together. The overarching goal of the Vision process is to set out a framework to do that. The Vision process is a prelude to detailed planning, which must include refined analyses of costs and benefits. The goal is more integrated planning going forward – for SIPs required by the federal Clean Air Act, AB 32 Scoping Plan updates, and freight transport planning over the next couple of years.

The federally approved 2007 SIPs for the South Coast Air Basin and the San Joaquin Valley Air Basin call for broad use of advanced technologies, clean energy, and greater efficiencies to provide the foundation for meeting federal air quality standards. Additionally, SIPs for ozone for the revised federal ozone standard will need to provide for attainment by 2032. The 2008 Scoping Plan, required by California's Global Warming Solutions Act of 2006, similarly called for a statewide transition to clean energy and advanced technologies and outlined actions toward that end. For the long term, California has set for itself the 2050 goal of greenhouse gas emissions of 80 percent less than 1990 levels overall, and specifically 80 percent less than 1990 levels for the transportation sector.[1] The federal standard for ozone is reevaluated on a periodic basis and is also likely to be lowered further in the future as scientific studies continue to document health impacts of air pollution at progressively lower levels. The Vision process is an effort to begin to understand the interplay among strategies to meet air quality and climate goals, and to develop common and effective solutions to both.

As described in the June 27, 2012 Public Review Draft, staff posed several key questions to better understand the scope of technology advancements needed to meet air quality and climate goals. These questions addressed topics such as what

[1] Governor Brown Executive Order B-16-2012

technologies, fuels and other strategies would be needed to meet local air quality and greenhouse gas goals; whether the strategies were the same for meeting both air quality and climate goals; the implications of federal air quality deadlines coming well before those for climate; energy infrastructure demands for coordinated air quality and greenhouse gas strategies; and consideration of emissions from upstream sources of energy used in mobile sources as vehicle and equipment fleets are transformed to advanced zero- and near-zero emission technologies.

To begin to answer these questions and lay a foundation for future coordinated planning for criteria pollutants regulated through air quality standards (i.e., criteria pollutants), toxic pollutants such as diesel particulate matter, and greenhouse gases, *Vision for Clean Air* uses quantitative scenarios. These scenarios examine the nature of the technology and fuel transformation needed to meet the multiple air quality and greenhouse gas milestones between now and 2050.

Vision Targets

Targets used in the Vision exercise are characterized as the percent reduction needed from today's emission levels in order to meet the federal air quality standards for ozone and the State's long-term goal to reduce greenhouse gas emissions to 80 percent below 1990 levels by 2050. New federal air quality standards for particulate matter are also expected in the near future. For a description of how targets were developed, please refer to the June 27, 2012 Public Review Draft of *Vision for Clean Air: A Framework for Air Quality and Climate Planning*.

Vision Tool

A spreadsheet-based tool developed from the Argonne National Laboratory Vision 2001 Model was used to evaluate the scenarios. The Argonne model was intended to be used to evaluate transportation energy policy questions in the context of greenhouse gas emissions. The *Vision for Clean Air* effort started with the Argonne model and was heavily modified and expanded, such that the tool used for *Vision for Clean Air* is fundamentally a different model.

Additional information on the Vision Tool can be found in the *ARB Vision Model Documentation Appendix*. That Appendix and ARB's Vision models for light-duty vehicles, heavy-duty vehicles, and off-road mobile sources can be accessed at http://www.arb.ca.gov/planning/vision/vision.htm.

Staff used the Vision tool in an iterative manner with subsequently more ambitious scenarios, which entail assumptions about the availability of cleaner engines and zero-emission technologies, cleaner fuels, and efficiency improvements.

Key Concepts for Achieving California's Air Quality and Climate Goals

As reported in the June 27, 2012 Public Review Draft of *Vision for Clean Air: A Framework for Air Quality and Climate Planning,* the scenarios illustrate seven key concepts that together provide a foundation for coordinated solutions to California's air quality and climate goals.

- **Technology Transformation:** Transformation to advanced, zero-and near-zero emission technologies, renewable clean fuels, and greater efficiency that can achieve both federal air quality standards and climate goals.

- **Early Action:** Acceleration of the pace of transformation to meet federal air quality standard deadlines, with early actions to develop and deploy zero- and near-zero technologies also needed to meet climate goals.

- **Cleaner Combustion:** Advanced technology NOx emissions standards for on- and off-road heavy-duty engines beyond the cleanest available today to meet federal air quality standards in a timely manner.

- **Multiple Strategies:** A combination of strategies — technology, energy, and efficiency — applied to each sector.

- **Federal Action:** Federal actions, in addition to actions by state and local agencies and governments, to help clean-up sources that travel nationally and internationally such as trucks, ships, locomotives and aircraft.

- **Efficiency Gains:** Greater system and operational efficiencies to mitigate the impacts of growth, especially in high-growth freight transport sectors and vehicle efficiency gains to reduce fuel usage and mitigate the cost of new technologies.

- **Energy Transformation:** Transformation of the upstream energy sector and its greenhouse gas and smog forming emissions concurrent with the transformation to advanced technologies downstream.

This Appendix provides information about the scenarios that were run, documenting assumptions that were made, and providing results of model runs.

Scenario Development

Vision for Clean Air takes a broader approach and uses scenarios to illustrate the change needed in multiple milestone years to meet future emissions targets. This effort is not a plan, but rather, it provides valuable insight for future planning efforts that will include a stakeholder input process. This long-term approach is more common in greenhouse gas analyses. The advantage of long-term planning is that it reveals the scope of advanced technologies needed, how quickly the technologies need to come on line, and the key decision points for technology development and deployment along the way.

A scenario is a combination of technology, energy, and efficiency assumptions that change over time. Scenarios represent a projection of what could be possible — a “what if” story that provides context for decision-making. Scenarios are intended to inform decision-making but are not predictions of what the future will be. So rather than being a list of State Implementation Plan or SIP-ready control measures, the scenarios provide a view of a mix of technologies that could be successful in helping California meet its multi-pollutant goals. Further, the scenarios do not represent a policy choice that favors certain technologies and fuels over others. This scenario planning effort does not identify winners or losers on a specific path to meet air quality and climate goals. Rather, it demonstrates a combination of technologies and fuels that yield the scale of needed transformation. Any other mix of technologies and fuels achieving equivalent or better regional criteria pollutant and life cycle greenhouse gas reductions can be considered part of the scenario.

Scenarios were developed through an iterative process of assuming varying levels of technology sales penetration, fuel supply, and efficiency changes. These are ambitious assumptions going beyond the existing programs, and could be expected to require further actions, such as innovation, investment, incentives, and regulations to achieve. However, the scenarios do not include actions such as further incentive funding to accelerate penetration of advanced technologies and clean fuels to meet federal air quality deadlines. For example, expedited turnover of vehicles, as has been achieved with incentives programs implemented by State and local jurisdictions, is not assumed in the scenarios. All of the scenarios include as the starting point all technology and fuel regulations in place today, including passenger vehicle standards, truck and engine standards, the low carbon fuel standard, and the 33 percent renewable electricity requirement.

How Scenarios Were Developed

- Start with benefits of existing programs
- Develop storylines for further improvements in efficiency and cleaner technology, fuels, and energy sources
- Look at multi-pollutant results to inform scenario development

Scenario Description Overview and Combined Sector Results

For the Vision exercise, staff evaluated scenarios for the following sectors of mobile sources:

- Passenger vehicles
- On-road heavy-duty vehicles
- Freight and passenger locomotives
- Cargo handling equipment
- Commercial harbor craft
- Commercial ships (ocean going vessels)
- Off-road vehicles
- Aviation

Staff also evaluated the upstream energy needs and emission impacts associated with powering the mobile source sectors.

For each of the sectors, staff built upon a progressive set of assumptions when developing scenarios. The results of each sector's scenario runs were evaluated against the targets identified for specific milestone years to meet criteria and greenhouse gas goals. Staff developed three scenarios with increasing reliance on new technologies, fuels and energy sources to meet the targets. These three scenarios are described in general terms below, as are the combined results for all evaluated sectors in each scenario. Sector-specific assumptions and results for each of these scenarios are described later in this Appendix.

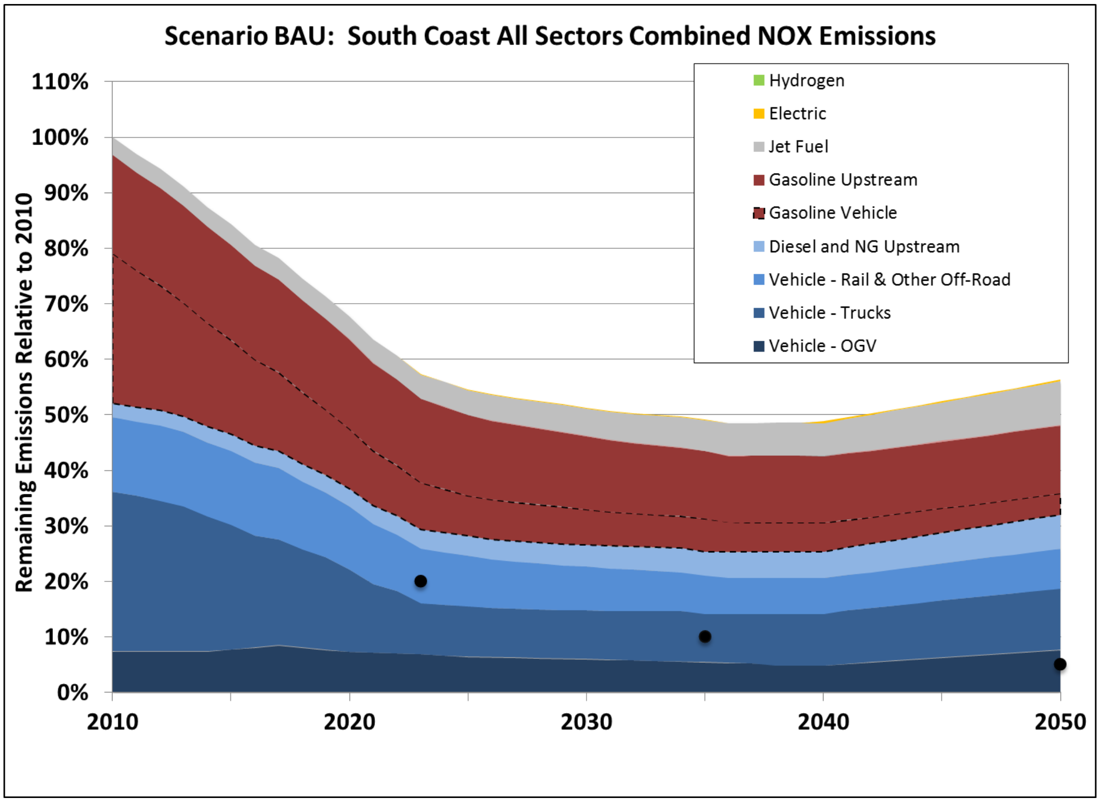
The June 27, 2012 Public Review Draft *Vision for Clean Air Appendix: Actions for Development, Demonstration, and Deployment of Needed Advanced Technologies* describes various advanced technologies that have the potential to be part of the transformation envisioned to meet the federal air quality standards and climate change goals. These advanced technologies are in varying stages of development and commercialization. In developing scenarios, staff made assumptions about the introduction and deployment of many advanced technologies described in that Appendix.

Selection by staff of technologies in scenario runs does not represent a policy choice that favors certain technologies over others. Instead they are included to provide a view of the types of technologies that could be successful in helping California meet its multi-pollutant goals. It is expected that there are technologies not included here that will ultimately be an important part of meeting the air quality standards and the State's climate goals. Neither the scenarios run nor the technologies modeled were intended as a list of SIP-ready control measures, or a nod of approval toward certain technologies. Staff expects that there are technologies not included in scenario runs that will ultimately be an important part of meeting the air quality standards and the State's climate goals.

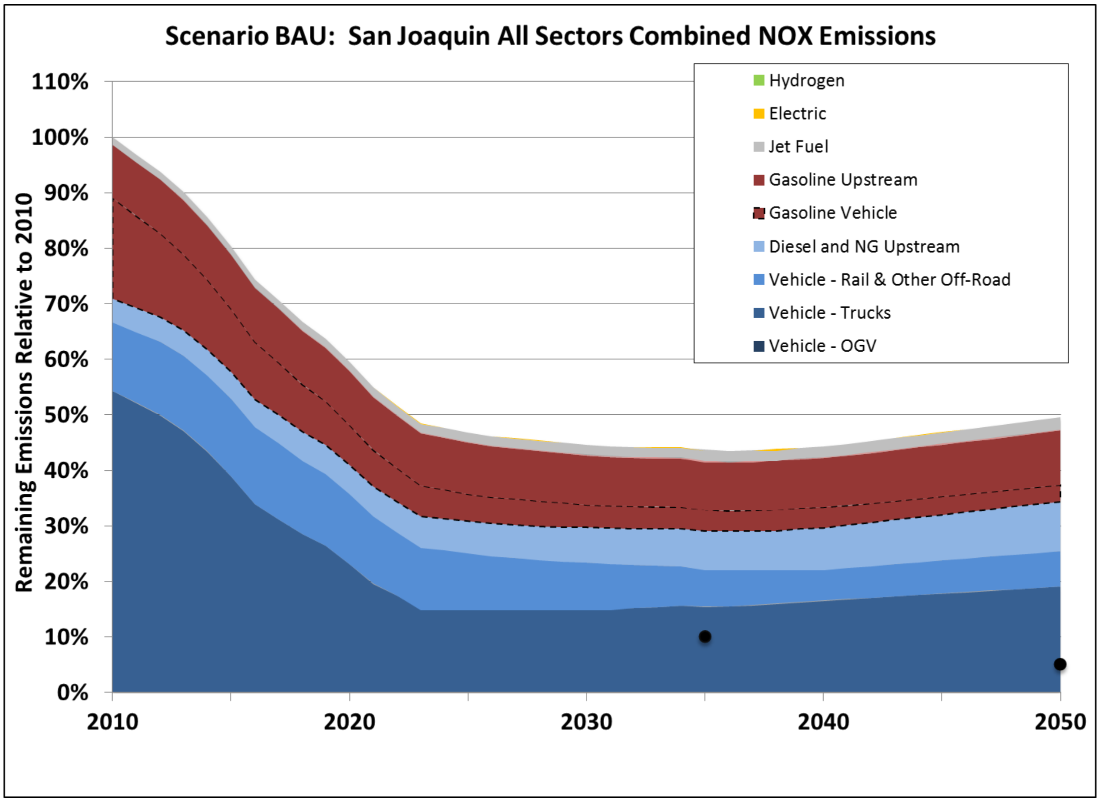
Vision for Clean Air provides a framework for future air quality and climate planning. Those planning efforts, entailing decisions on what advanced technologies to pursue, timeframes, and implementation mechanisms, must include consideration of cost, technical feasibility, trade-offs between near-term and longer-term emissions reduction potential, scalability from local and regional to statewide application, federal deadlines, and other factors.

Scenario 1 represents the business as usual approach. It includes all current federal and state programs and those programs that are "on the books" such as, adopted regulations that will be implemented in the future, the Advanced Clean Car Program, the 33 percent renewables target from the California Renewable Portfolio Standard and the California Low Carbon Fuel Standard (LCFS) goal of ten percent less carbon intensity by 2020.

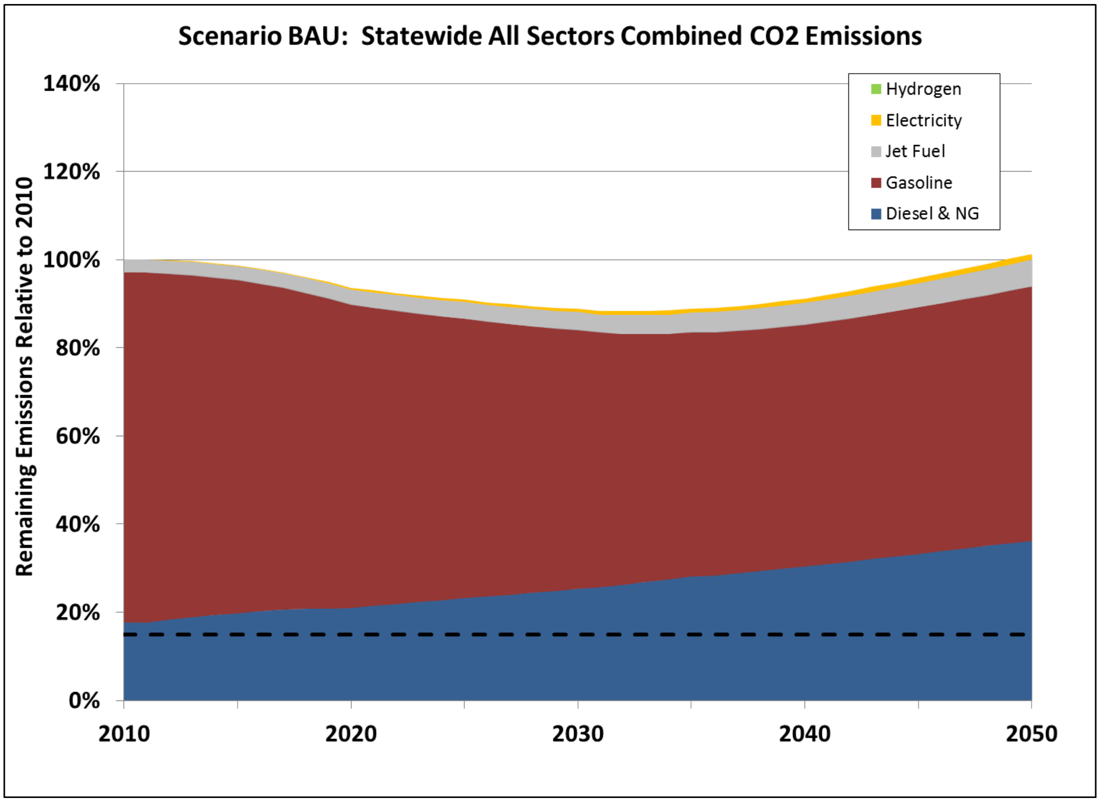
Shown below are Scenario 1 results from combining model runs for all evaluated sectors. The charts portray oxides of nitrogen (NOx) emissions in the South Coast and San Joaquin Valley between 2010 and 2050. Emissions are shown on a percentage basis, relative to levels in each region in 2010. Another chart shows combined carbon dioxide (CO2) emissions from the same mobile source sectors. NOx emission targets for each region are shown in circles, while the CO2 target is shown as a dashed line. In this document, the NOx emissions charts are separated by region while the CO2 emissions charts represent statewide emissions.



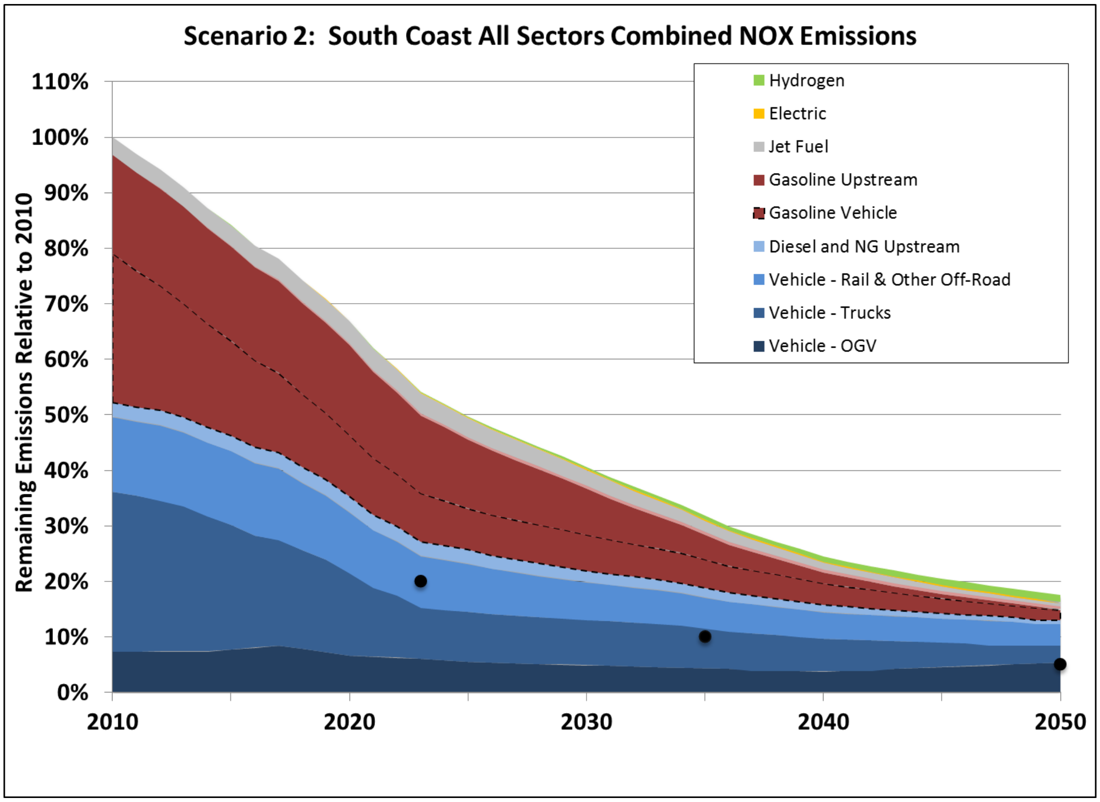
Scenario BAU: South Coast All Sectors Combined NOX Emissions
Remaining Emissions Relative to 2010
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
2010
2020
2030
2040
2050
Hydrogen
Electric
Jet Fuel
Gasoline Upstream
Gasoline Vehicle
Diesel and NG Upstream
Vehicle - Rail & Other Off-Road
Vehicle - Trucks
Vehicle - OGV

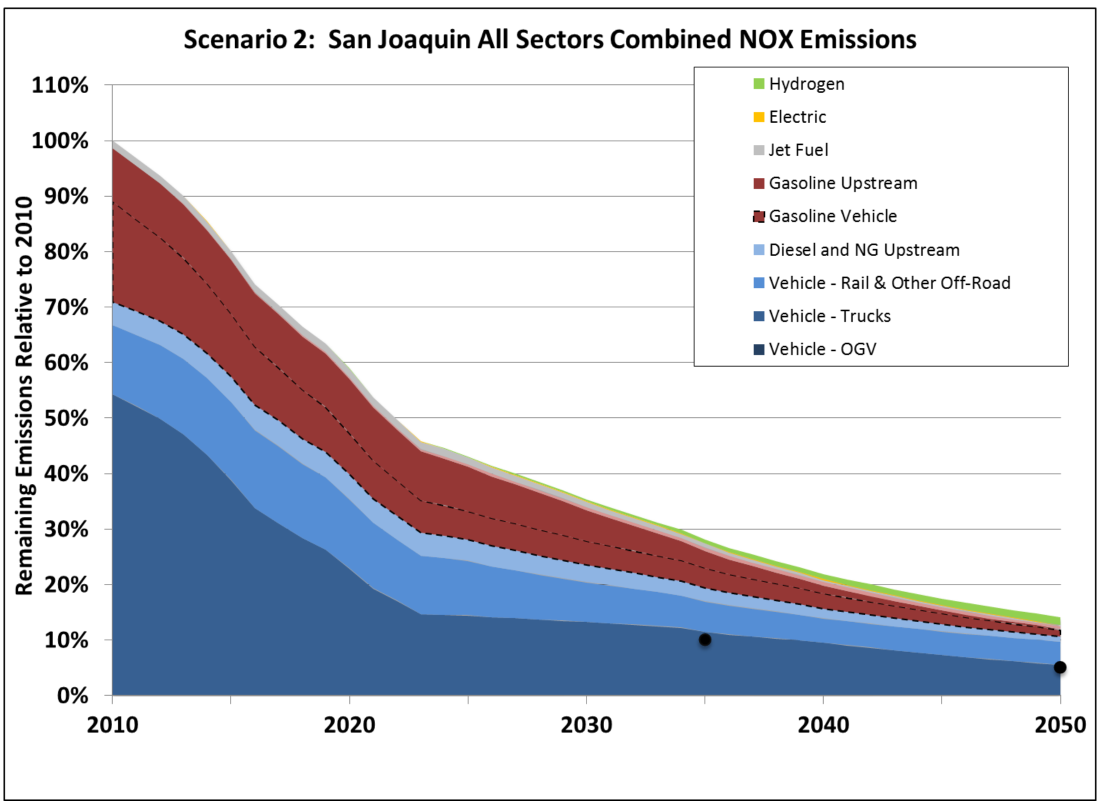


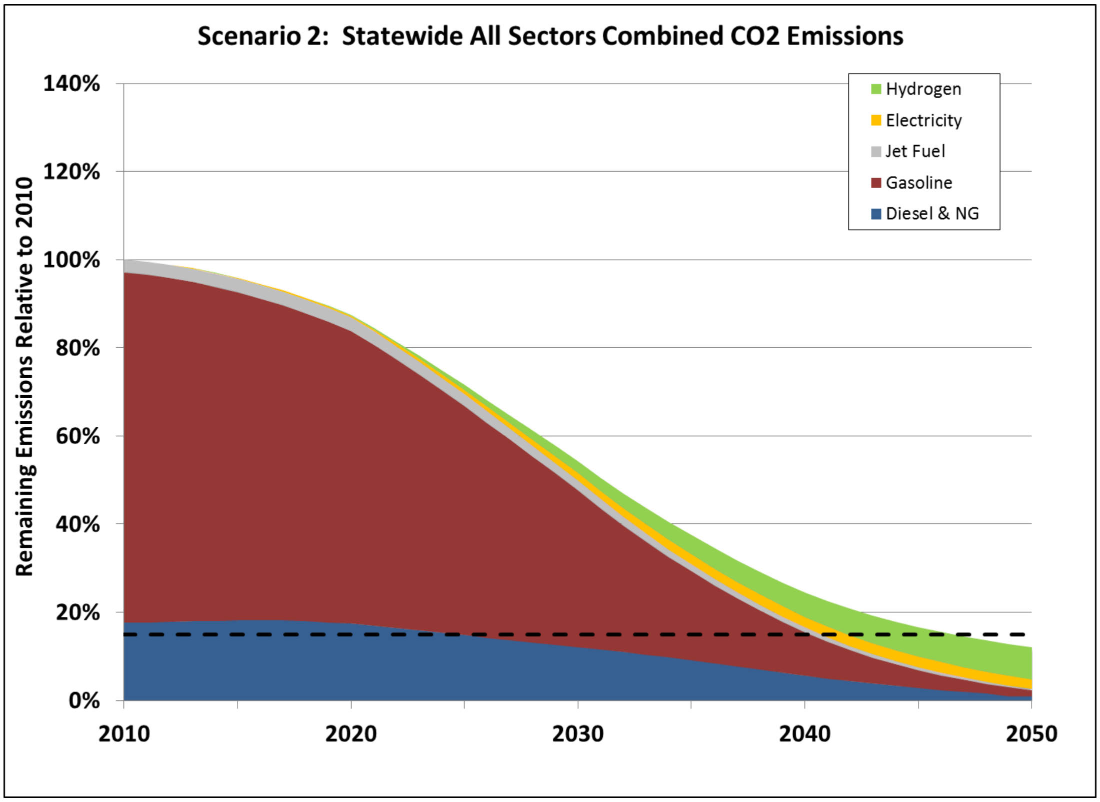
Scenario BAU: San Joaquin All Sectors Combined NOX Emissions
Remaining Emissions Relative to 2010
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
2010
2020
2030
2040
2050
Hydrogen
Electric
Jet Fuel
Gasoline Upstream
Gasoline Vehicle
Diesel and NG Upstream
Vehicle - Rail & Other Off-Road
Vehicle - Trucks
Vehicle - OGV



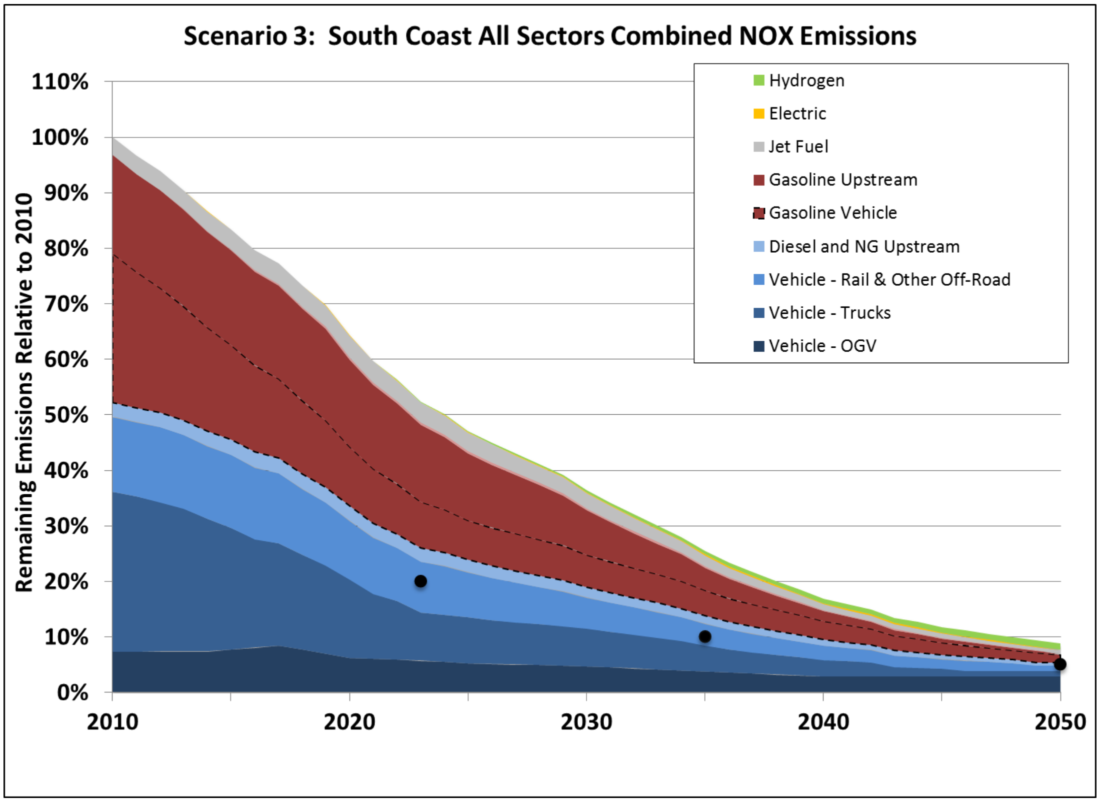
Scenario 2 builds upon Scenario 1 by including a phased transition to advanced technologies and sustainable fuels. It includes the business as usual programs in Scenario 1, plus new technologies and fuels such as electric and hydrogen passenger vehicles, hybrid heavy-duty truck technologies and a conversion to hydrogen, electricity and natural gas to fuel the transportation sector. For port and rail associated activity, this scenario includes lower growth rates in the future years and increases in fuel economy and efficiencies. For aviation, this scenario includes the Federal Aviation Administration's Continuous Lower Energy, Emissions, and Noise (CLEEN) program that sets NOx and greenhouse gas reduction targets of 70 to 75 percent by approximately 2030.

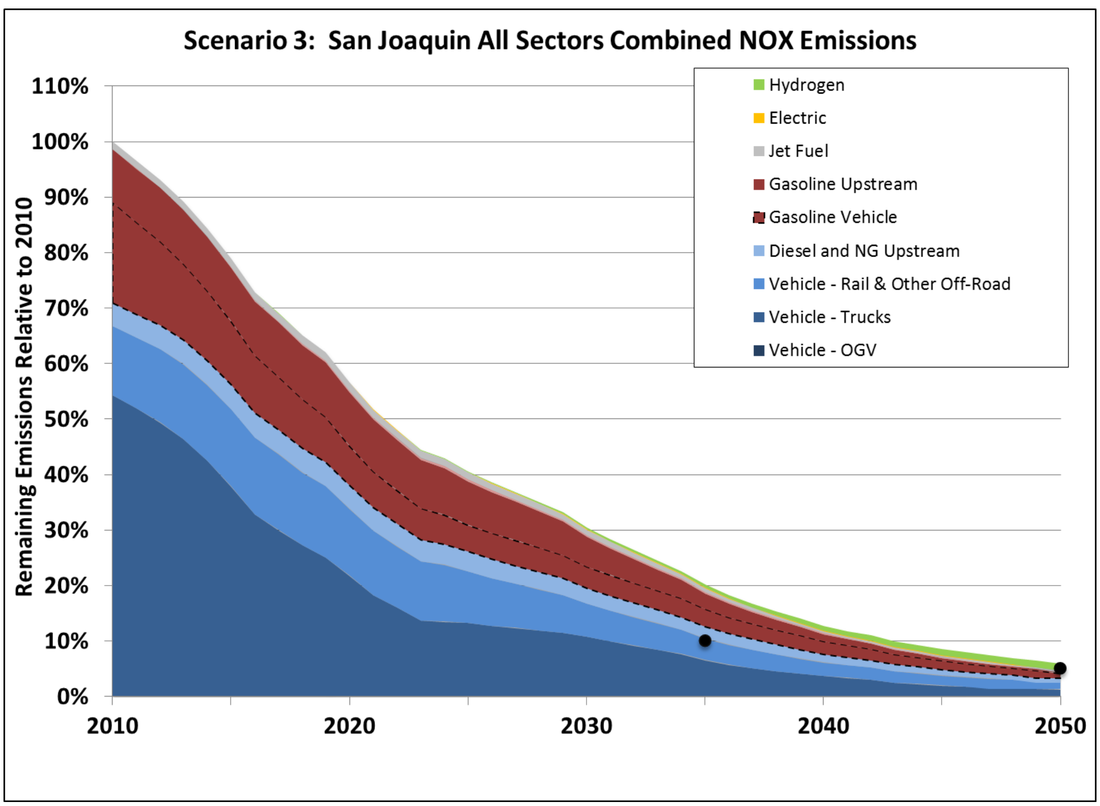

Scenario 2: South Coast All Sectors Combined NOX Emissions
Remaining Emissions Relative to 2010
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
2010
2020
2030
2040
2050
Hydrogen
Electric
Jet Fuel
Gasoline Upstream
Gasoline Vehicle
Diesel and NG Upstream
Vehicle - Rail & Other Off-Road
Vehicle - Trucks
Vehicle - OGV

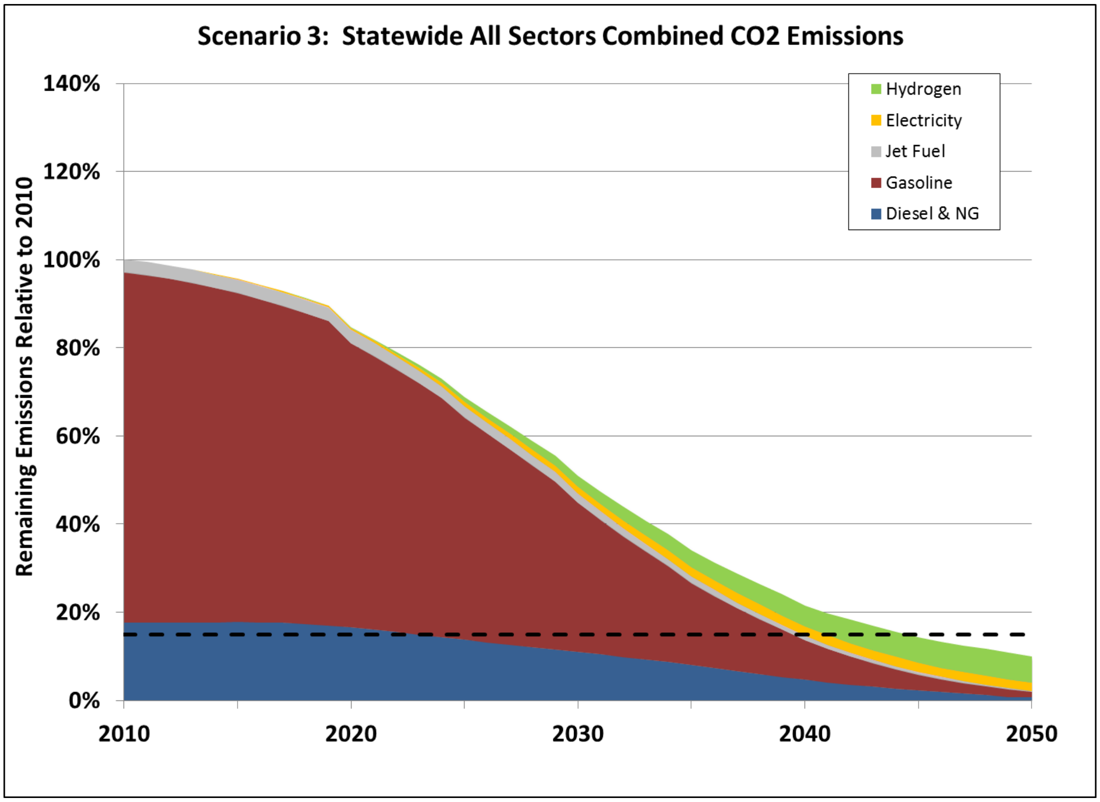

Scenario 2: San Joaquin All Sectors Combined NOX Emissions
Remaining Emissions Relative to 2010
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
2010
2020
2030
2040
2050
Hydrogen
Electric
Jet Fuel
Gasoline Upstream
Gasoline Vehicle
Diesel and NG Upstream
Vehicle - Rail & Other Off-Road
Vehicle - Trucks
Vehicle - OGV



Scenario 3 builds upon Scenario 1 and 2 by including cleaner near-term combustion in the form of another round of aggressive, future NOx emissions standards and a phasing of ten to twenty percent reduction in activity by 2050. For ships, this scenario includes an increase in the use of shore power, improved efficiency, and cleaner fuel. For Aviation, this scenario does not include additional NOx emission reductions over Scenario 2, but does include the additional phasing in of ten to twenty percent reductions in activity by 2050.


Scenario 3: South Coast All Sectors Combined NOX Emissions
Remaining Emissions Relative to 2010
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
2010
2020
2030
2040
2050
Hydrogen
Electric
Jet Fuel
Gasoline Upstream
Gasoline Vehicle
Diesel and NG Upstream
Vehicle - Rail & Other Off-Road
Vehicle - Trucks
Vehicle - OGV

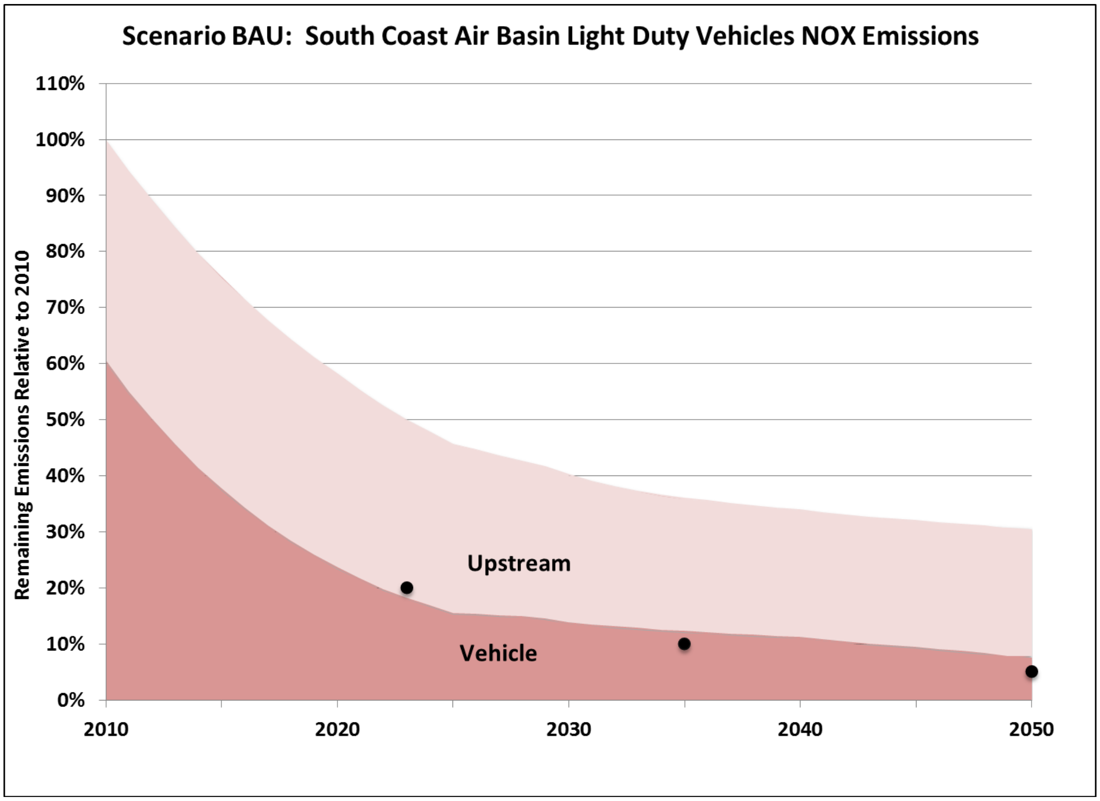

Scenario 3: San Joaquin All Sectors Combined NOX Emissions
Remaining Emissions Relative to 2010
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
2010
2020
2030
2040
2050
Hydrogen
Electric
Jet Fuel
Gasoline Upstream
Gasoline Vehicle
Diesel and NG Upstream
Vehicle - Rail & Other Off-Road
Vehicle - Trucks
Vehicle - OGV

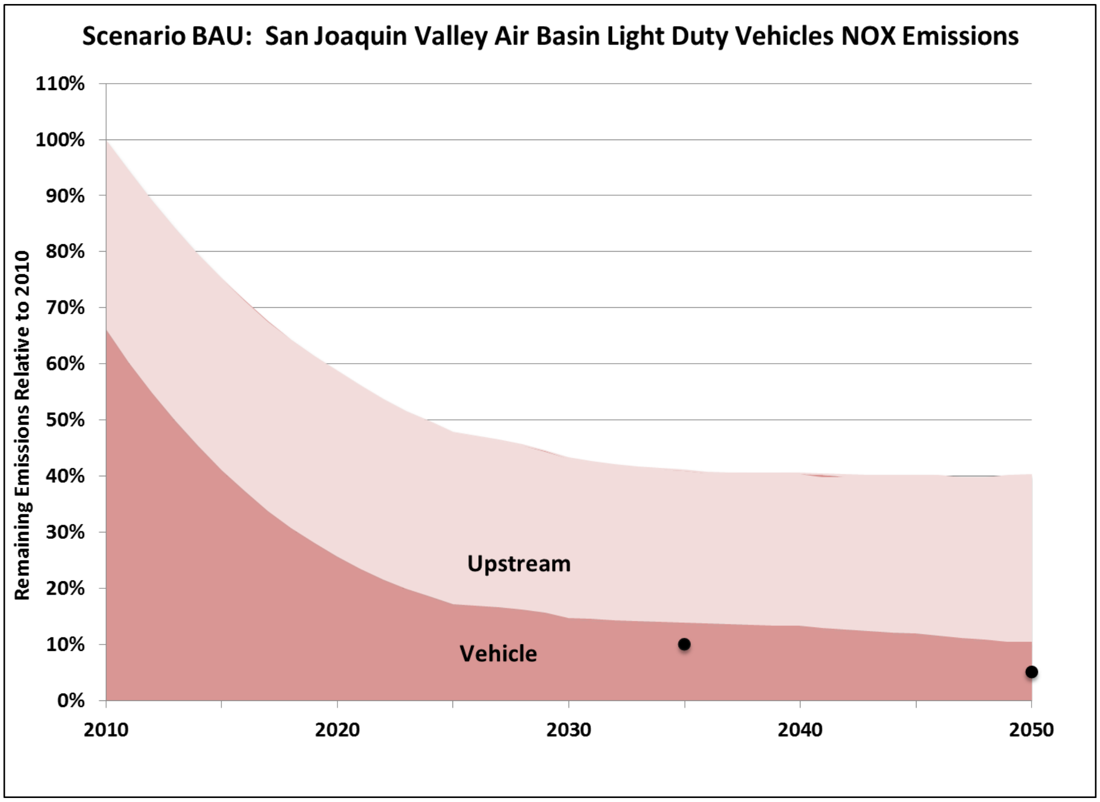

Scenario 3: Statewide All Sectors Combined CO2 Emissions
Remaining Emissions Relative to 2010
140%
120%
100%
80%
60%
40%
20%
0%
2010
2020
2030
2040
2050
Hydrogen
Electricity
Jet Fuel
Gasoline
Diesel & NG

Passenger Vehicles

The number of passenger cars and mileage in the future is based on the same assumptions used in ARB's EMFAC 2011 model. EMFAC in turn draws from California Department of Motor Vehicles registration data, Metropolitan Transportation data on vehicle use, and annual mileage accrual from the State's Smog Check database. The pace at which new cars—and new cleaner technologies—enter the fleet is also based on EMFAC assumptions about vehicle sales and retirement rates.

Scenario 1: The BAU scenario reflects the programs and regulations that are currently in place and fully implemented as well as adopted standards and regulations with future implementation dates. This includes the Advanced Clean Car program, the 33 percent Renewable Portfolio Standard, and the Low Carbon Fuel Standard of ten percent less carbon intensity by 2020. It also includes a straight-line projection that assumes the vehicle fuel economy and fuel carbon intensity values from 2025 to 2050 are fixed even as vehicle population grows.





Scenario 2: This scenario assumes the advanced technology choices and sales rates that ARB staff developed in 2009 to address the 2050 greenhouse gas target of 80 percent below 1990 emission levels. The 2009 staff analysis was part of the initial work informing the Advanced Clean Cars program; although the 2009 scenario was more aggressive than the regulation.

This scenario goes well beyond the Scenario 1 by adding the following:

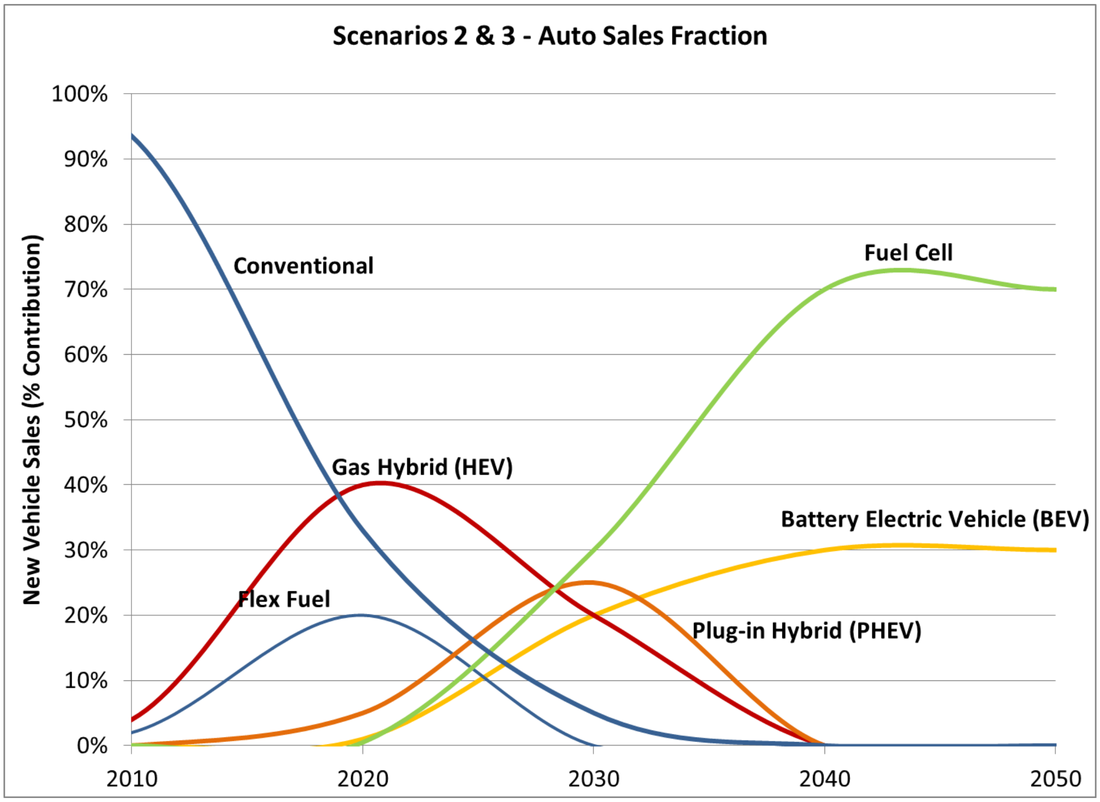
- An aggressive phase-in of alternative fuels and zero-emission vehicles such as plug-in electric vehicles and hydrogen fuel cell vehicles, and hybrid electric vehicles.

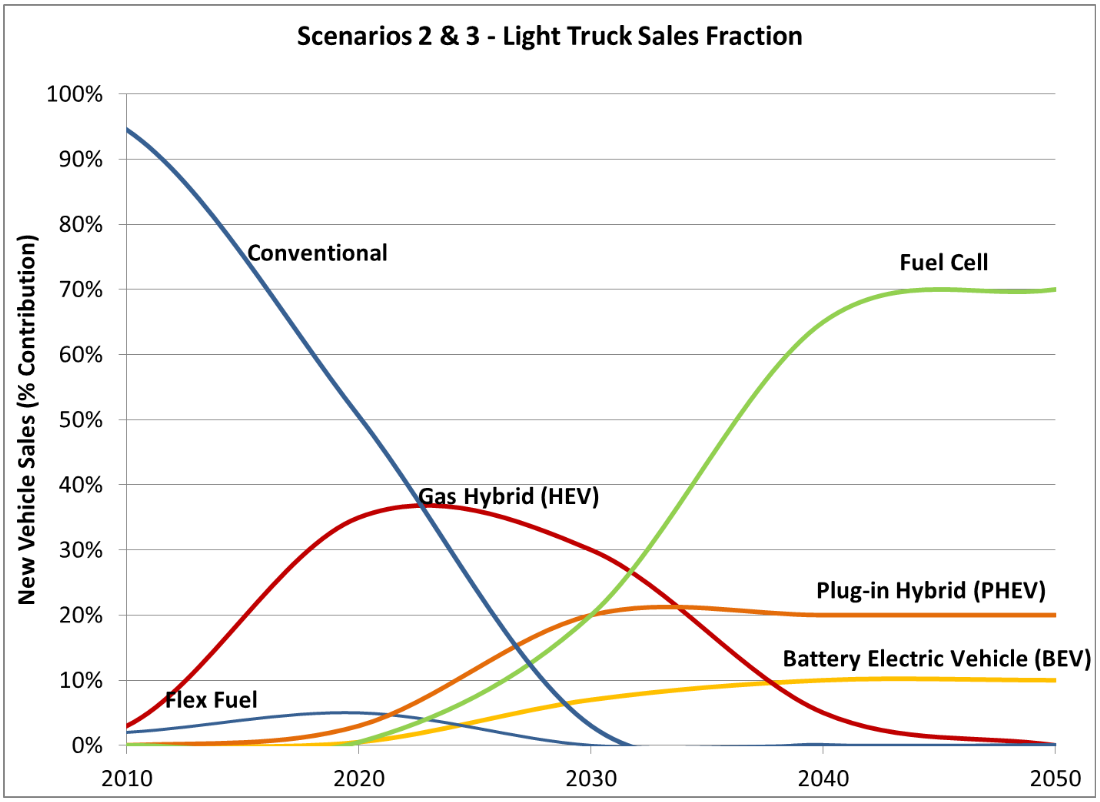
- A mix of fuel cell vehicles and battery electric vehicles based on varying performance needs within the sector (e.g. fuel cell vehicles are more appropriate for longer-range and heavier platforms).

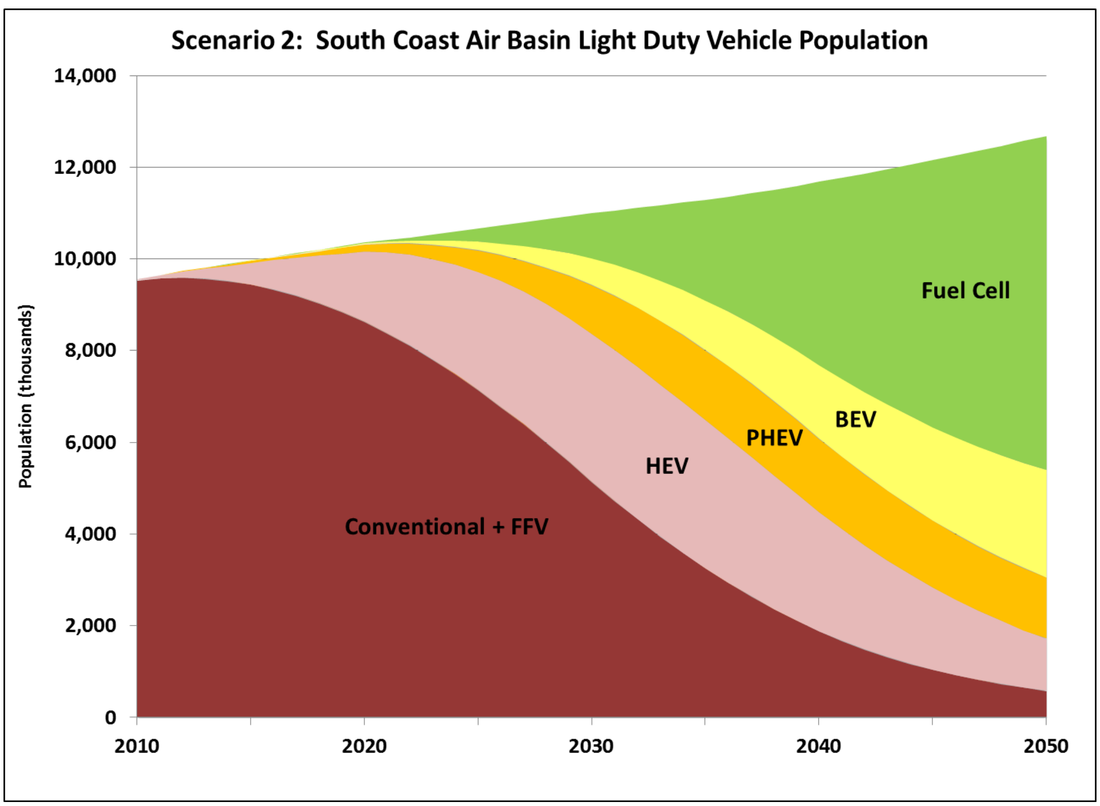
- Fuel economy improvements of approximately double that of today's cars that would result from a number of factors, including vehicle down-sizing and vehicle weight reduction, in addition to powertrain efficiency improvements.

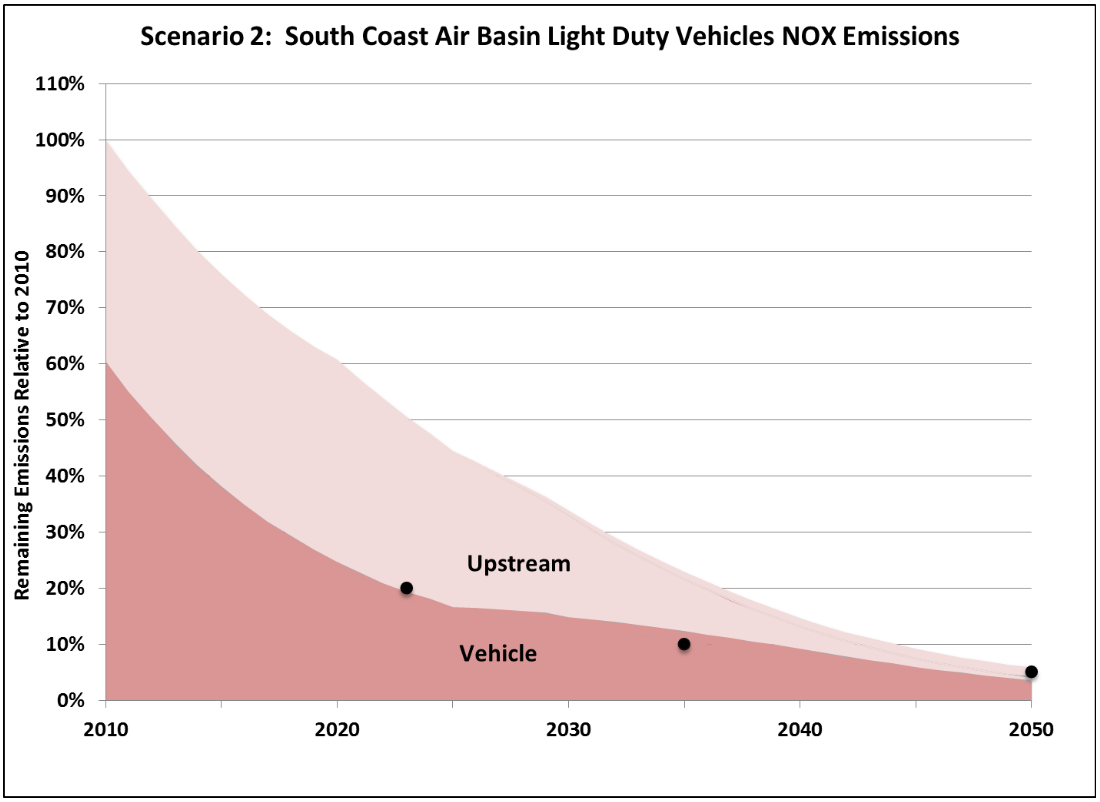
- Large shift in energy supply to hydrogen and grid electricity, both generated over the long-term from low-carbon intensity sources.

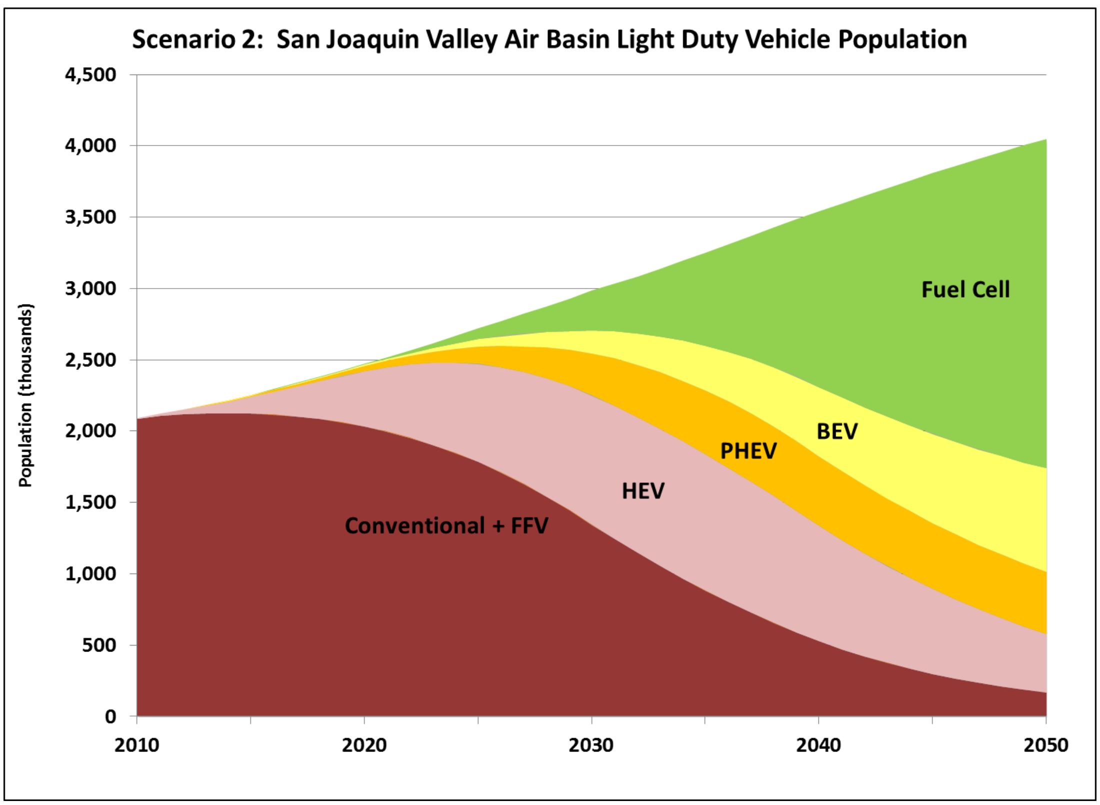
- Those vehicles still burning liquid fuels, such as hybrids, would be using increasingly advanced blends of renewable gasoline over time. The details of the energy mix for passenger vehicles and other sectors are discussed in the upstream fuel scenario, the energy sector.

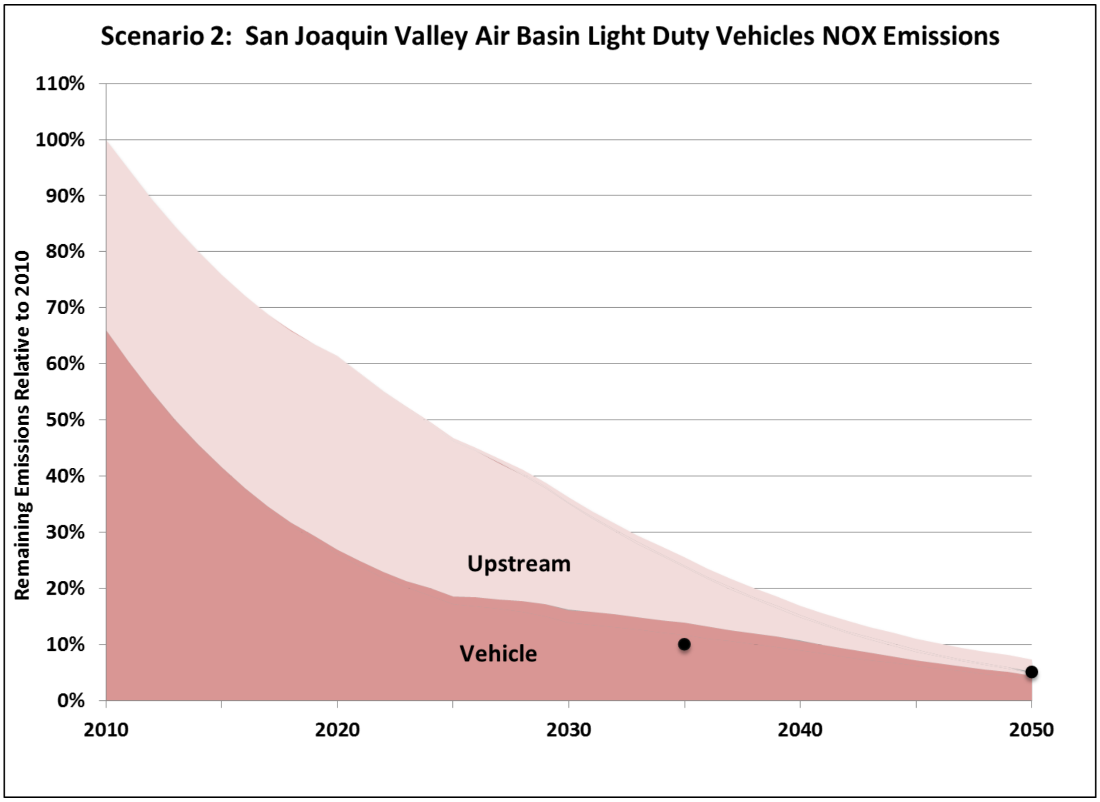



Scenarios 2 & 3 - Light Truck Sales Fraction
New Vehicle Sales (% Contribution)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
2010
2020
2030
2040
2050
Conventional
Fuel Cell
Gas Hybrid (HEV)
Plug-in Hybrid (PHEV)
Battery Electric Vehicle (BEV)
Flex Fuel

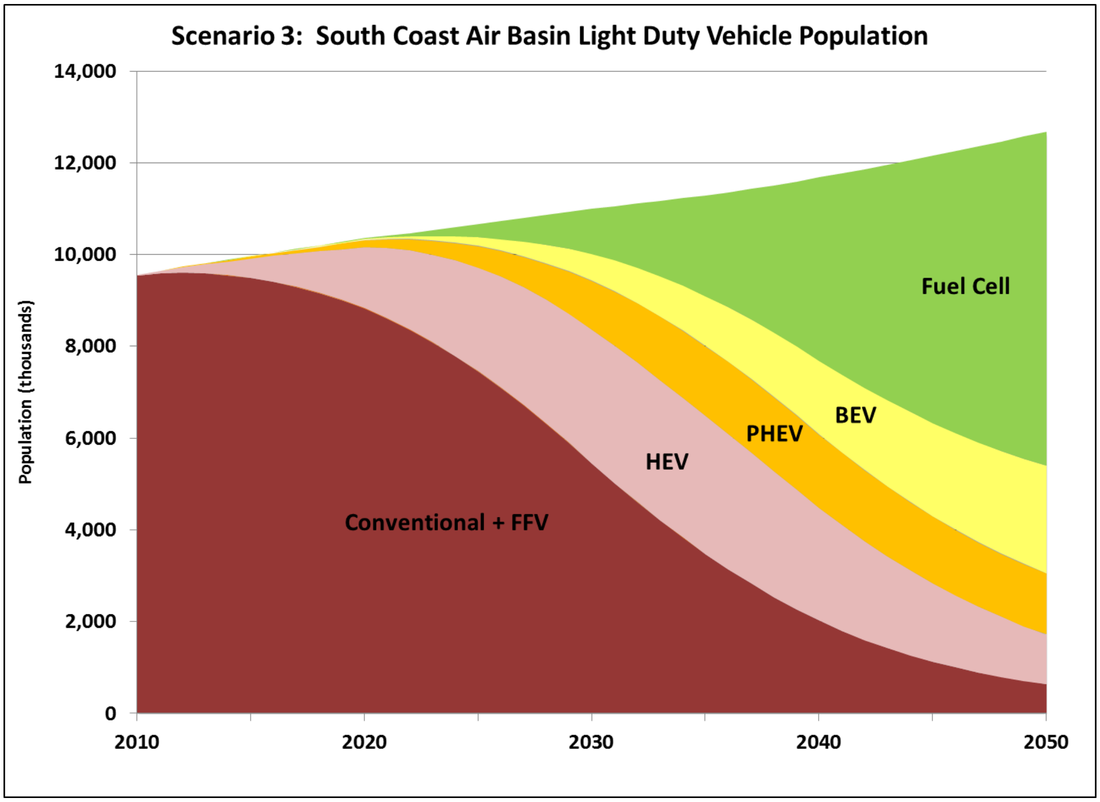

Scenario 2: South Coast Air Basin Light Duty Vehicle Population
Population (thousands)
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
2010
2020
2030
2040
2050
Fuel Cell
BEV
PHEV
HEV
Conventional + FFV

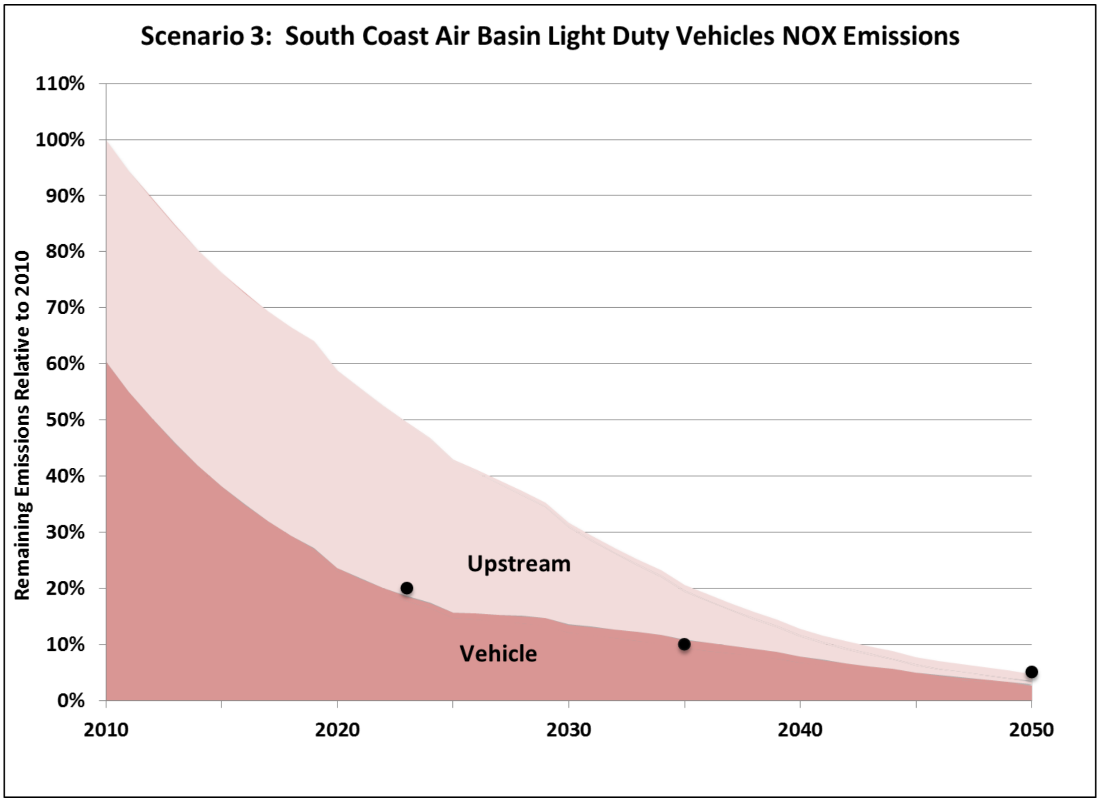

Scenario 2: South Coast Air Basin Light Duty Vehicles NOX Emissions
Remaining Emissions Relative to 2010
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
2010
2020
2030
2040
2050
Upstream
Vehicle

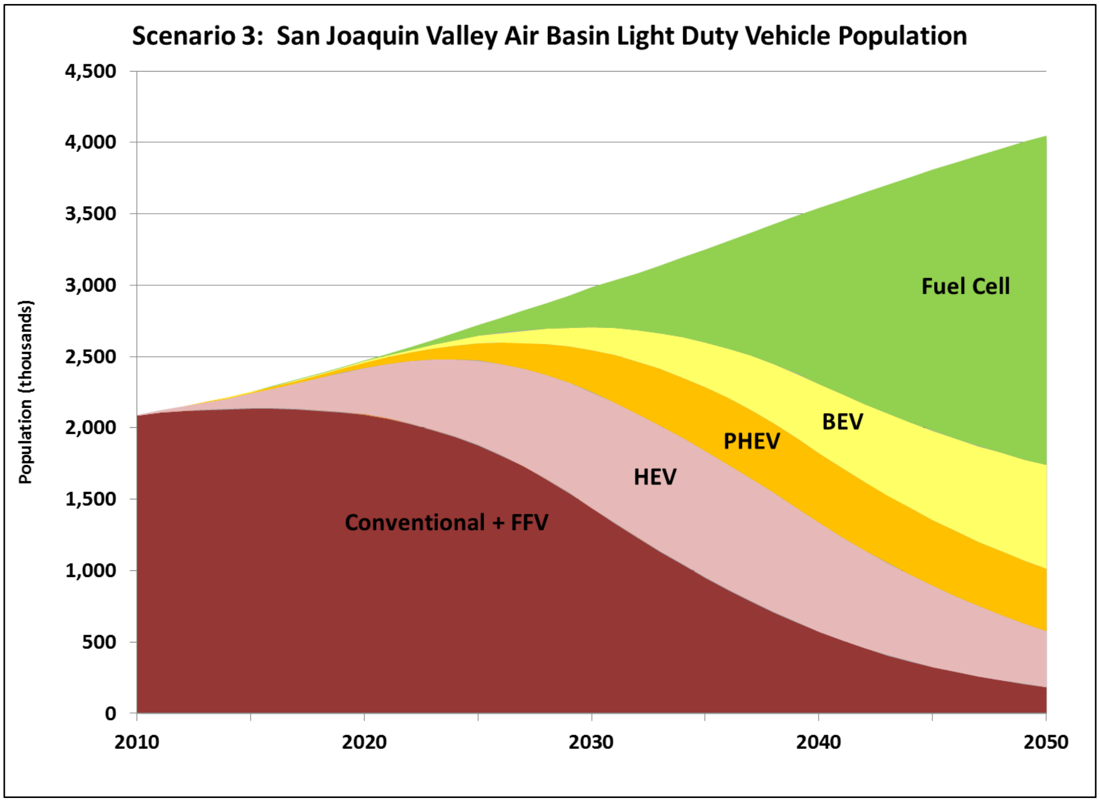

Scenario 2: San Joaquin Valley Air Basin Light Duty Vehicle Population
Population (thousands)
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
2010
2020
2030
2040
2050
Fuel Cell
BEV
PHEV
HEV
Conventional + FFV

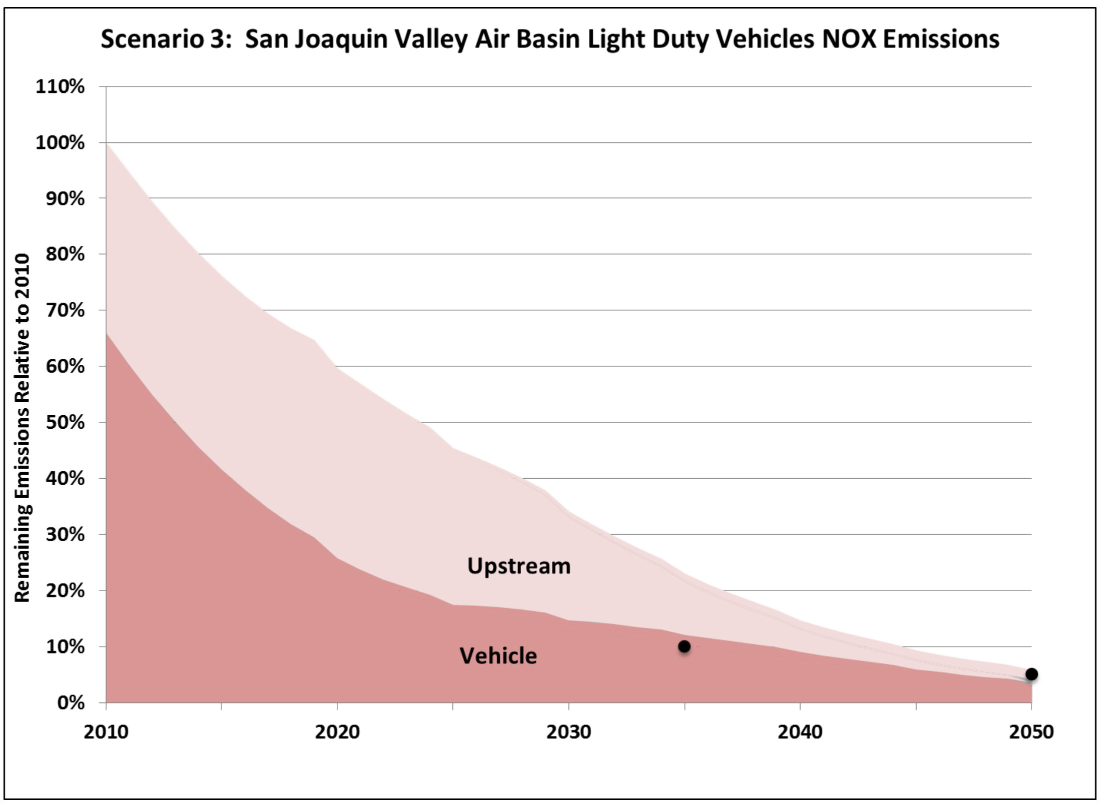


Scenario 3: The June 27, 2012 Public Review Draft refered to this scenario as the zero emission scenario. As with Scenario 2, this scenario assumes that from 2040 all new auto sales will comprise of zero emission vehicles. Scenario 3 builds on Scenario 2 with additional land use and transportation system improvements that yield a twenty percent reduction in vehicle miles traveled from 2050 BAU levels. This is phased in starting in 2035 assuming successful implementation of the existing Sustainable Communities Strategies and other regional planning efforts.


Scenario 3: South Coast Air Basin Light Duty Vehicle Population
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Population (thousands)
2010
2020
2030
2040
2050
Fuel Cell
BEV
PHEV
HEV
Conventional + FFV


Scenario 3: South Coast Air Basin Light Duty Vehicles NOX Emissions
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Remaining Emissions Relative to 2010
2010
2020
2030
2040
2050
Upstream
Vehicle


Scenario 3: San Joaquin Valley Air Basin Light Duty Vehicle Population
Population (thousands)
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
2010
2020
2030
2040
2050
Fuel Cell
BEV
PHEV
HEV
Conventional + FFV


Scenario 3: San Joaquin Valley Air Basin Light Duty Vehicles NOX Emissions
Remaining Emissions Relative to 2010
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
2010
2020
2030
2040
2050
Upstream
Vehicle

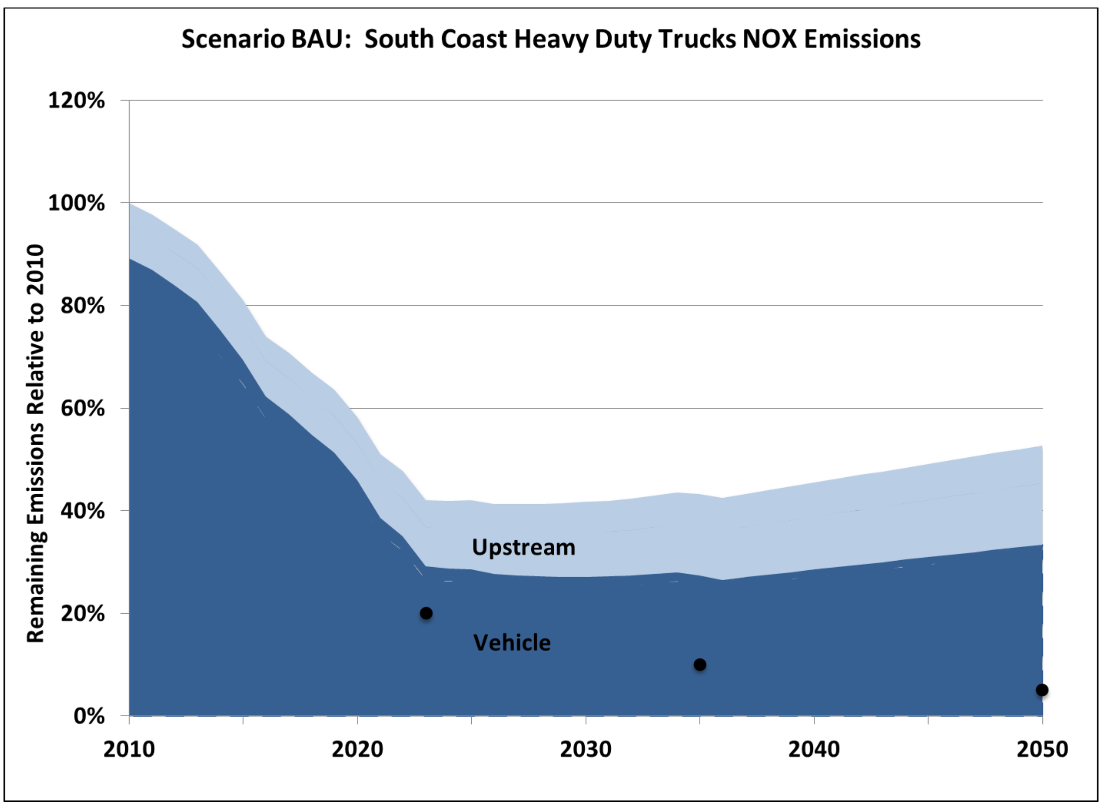
On-Road Heavy-Duty Vehicles

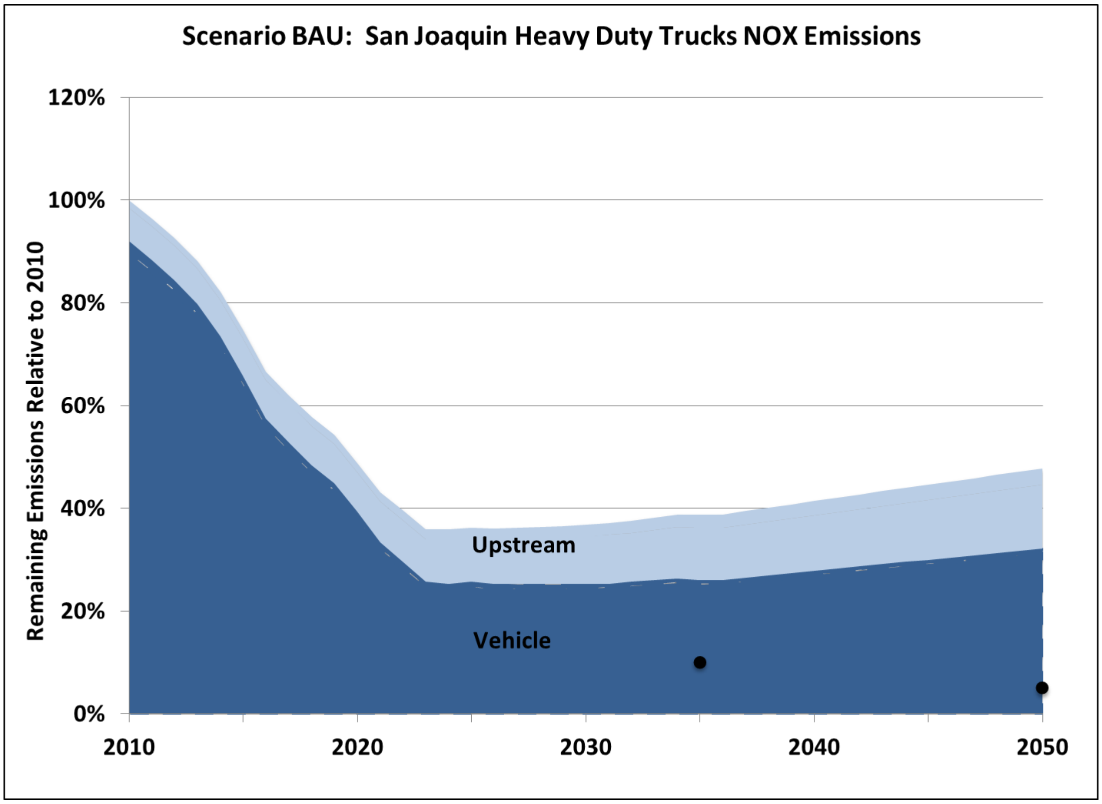
Similar to the light duty vehicles, the heavy duty truck sector was modeled in detail using a stock turn-over model. The ARB truck fleet assumptions in EMFAC 2011 model were used, including sales and retirement rates, and sector activity growth projections. Although all eight truck classifications were considered in developing assumptions, the model used a simplified approach with three broad fleets. This included an in-state heavy-heavy duty fleet (HHD), an out-of-state (OOS) heavy duty fleet, and an in-state medium heavy duty fleet (MHD).

Scenario 1: The BAU scenario reflects the programs and regulations that are currently in place and fully implemented as well as adopted standards and regulations with future implementation dates. This includes the current truck engine criteria pollutant emission standards, the federal truck efficiency standards, and the in-use fleet rules that reduce in-use emissions.

Several specific assumptions were made for the BAU scenario, including:

- Truck fuel efficiency values fixed at 2020 levels based on the federal efficiency standard
- Powertrain technology market shares (sales) fixed at 2010 levels (e.g. for medium heavy duty trucks, 60 percent gasoline and 40 percent diesel engines)





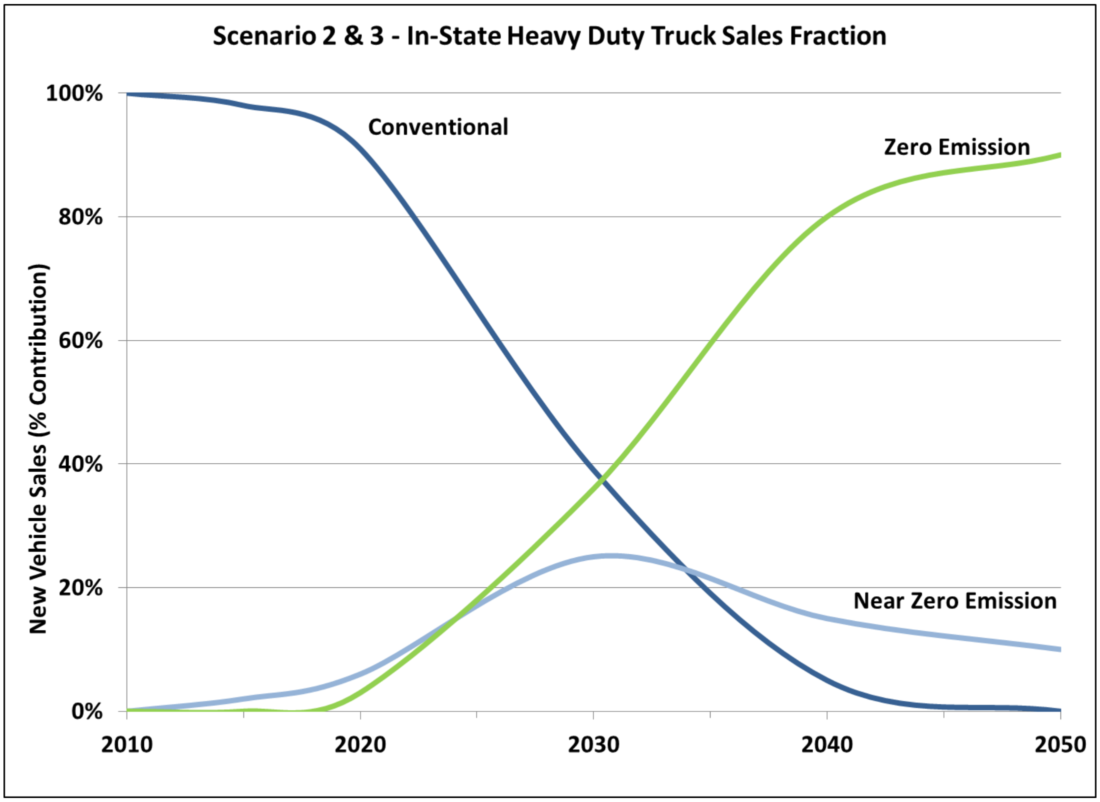
<u>Scenario 2</u>:
This scenario goes well beyond Scenario 1 by adding the following:

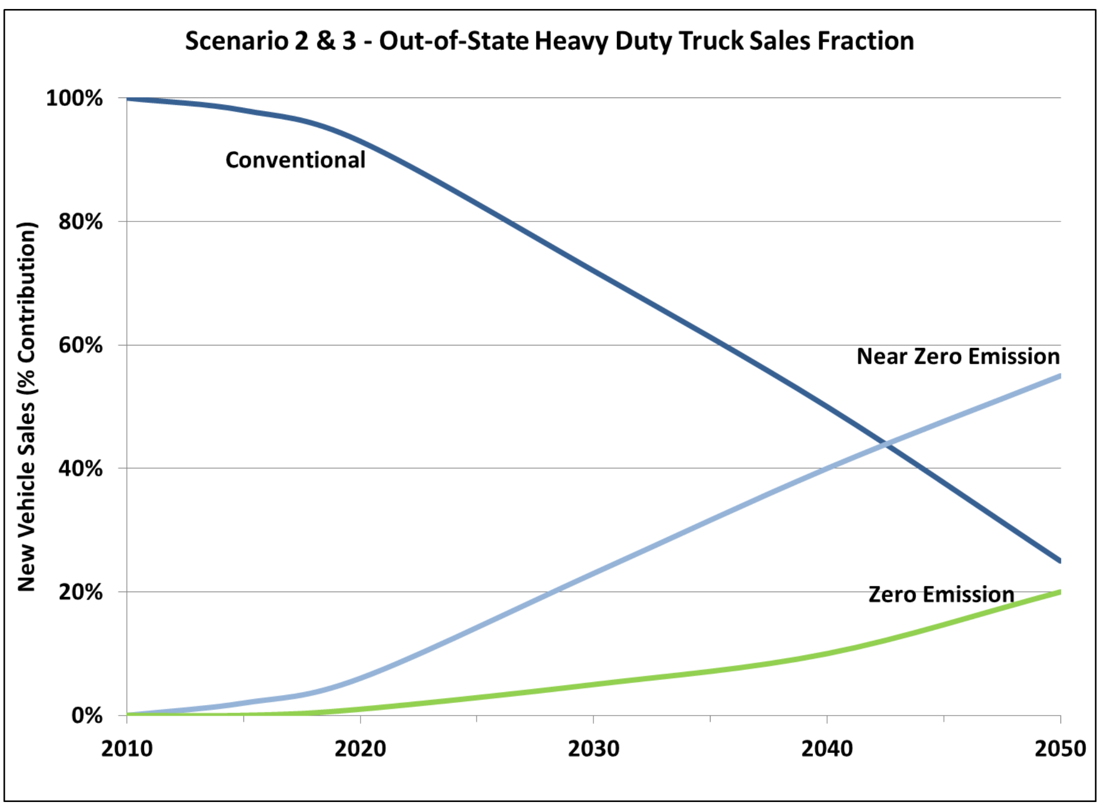
- A rapid transition to advanced technology was assumed at varying levels for the three fleets modeled. The table below shows the main technologies modeled, but represents one of many possible scenarios.

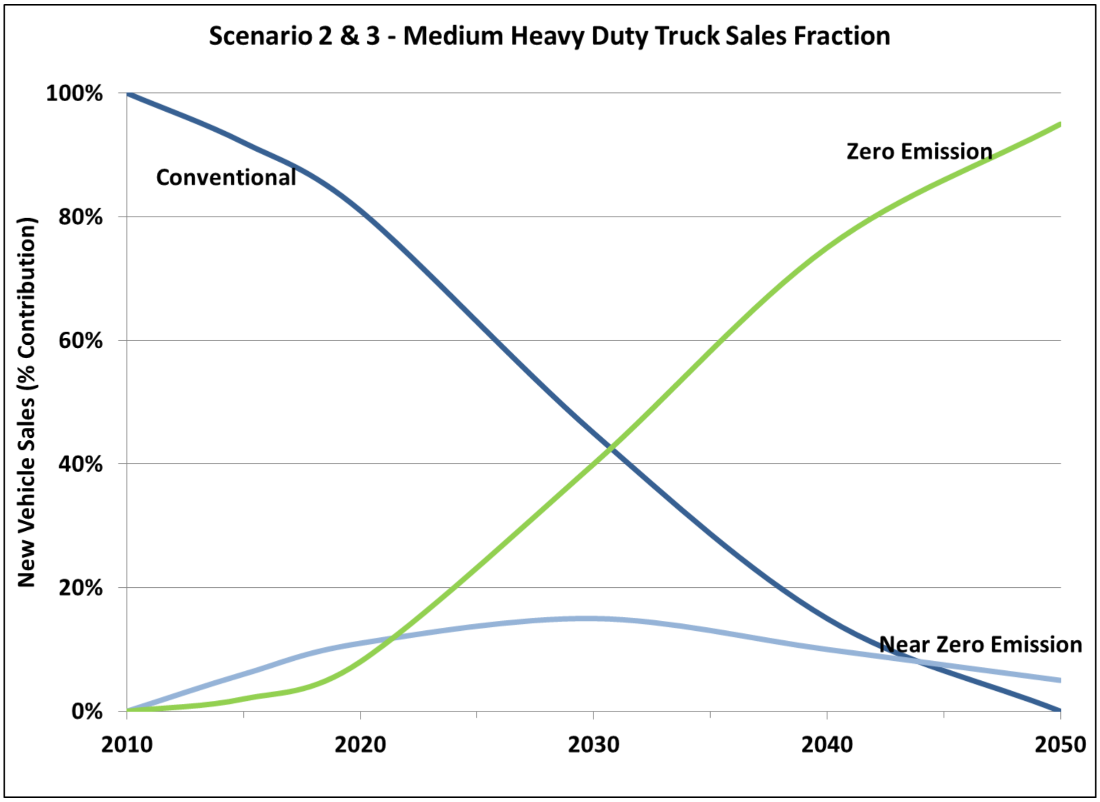
Market Share (sales percent) by technology type in 2050 for Scenario 2

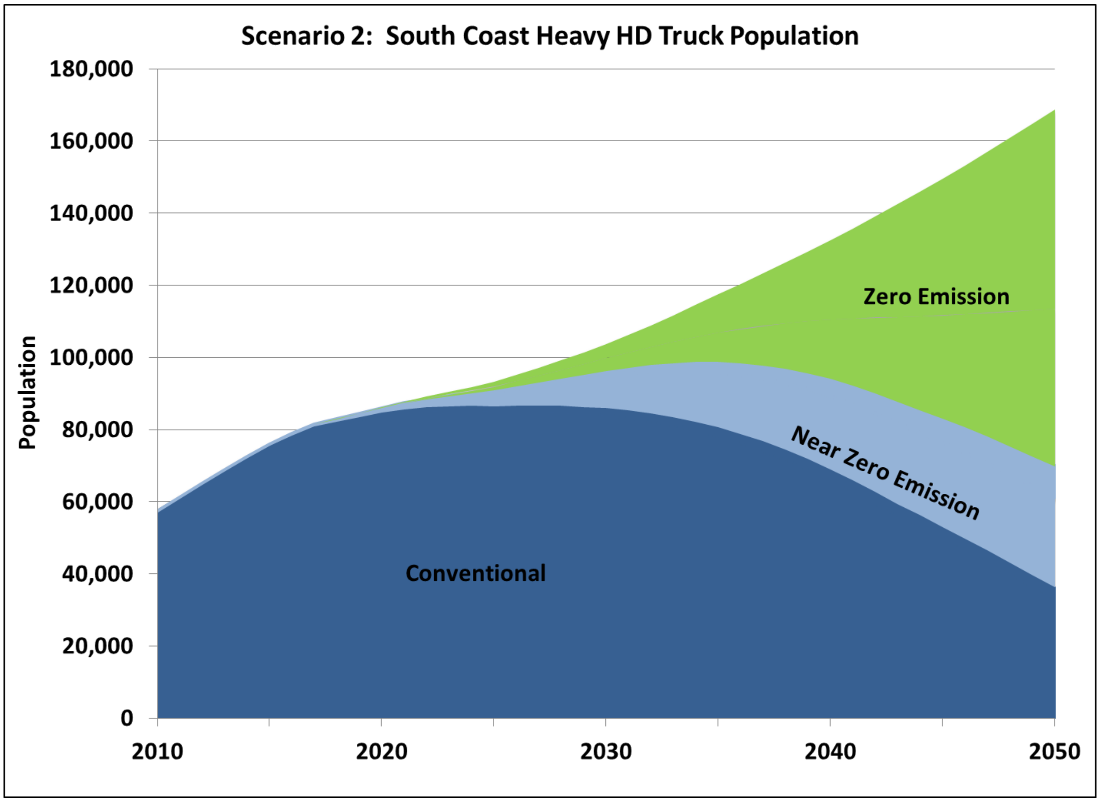
	In-state HHD	Out-state HHD	In-state MHD
Plug-in hybrid	5	5	5
Battery electric	45	10	45
Fuel cell electric	45	10	50
Hybrid (no plug)	5	50	
Conventional (Diesel and Natural Gas)		25	

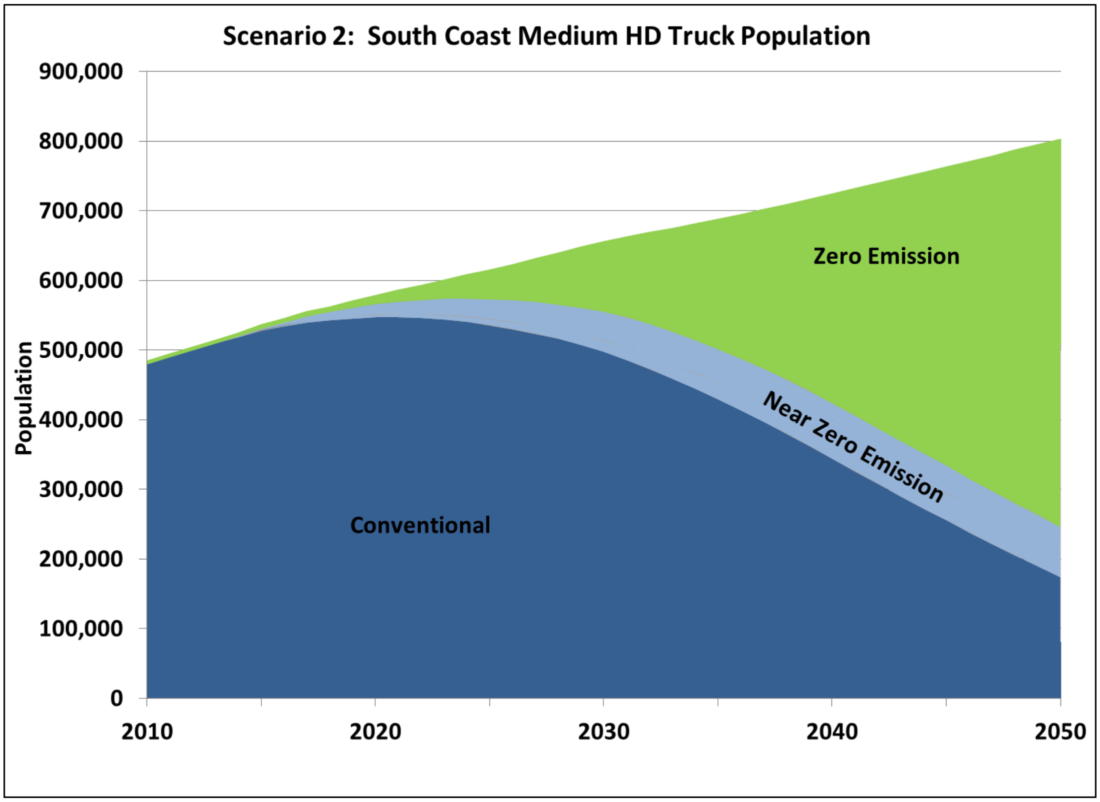
- Plug-in hybrid technology for trucks could be implemented with either a grid-charged battery, or a wayside power (e.g. catenary) hookup along routes.
- An alternate case was developed with much lower technology market growth and a complete reliance on advanced biofuels. Although a near equal reduction in greenhouse gas reductions can occur, vehicle criteria pollutant emissions for this case remain much higher than the main case for Scenario 2.
- Truck vehicle efficiency doubles by 2050 from current 2010 levels.

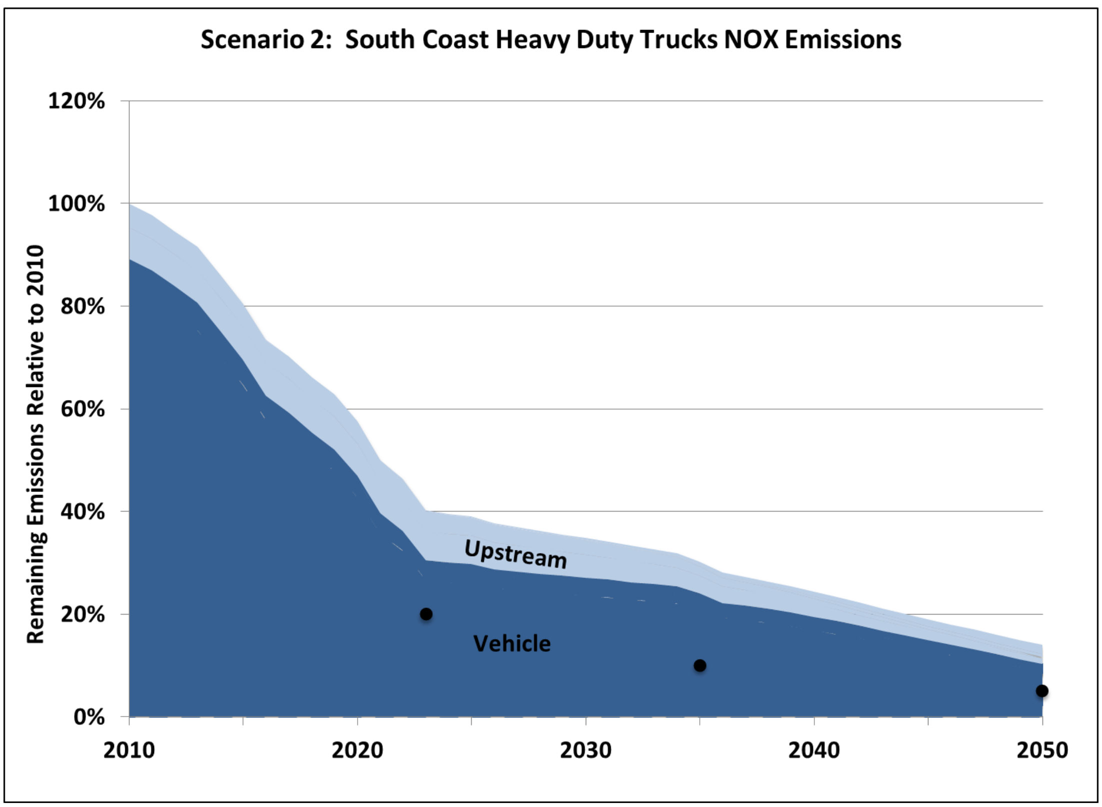

Scenario 2 & 3 - In-State Heavy Duty Truck Sales Fraction
New Vehicle Sales (% Contribution)
100%
80%
60%
40%
20%
0%
2010
2020
2030
2040
2050
Conventional
Zero Emission
Near Zero Emission

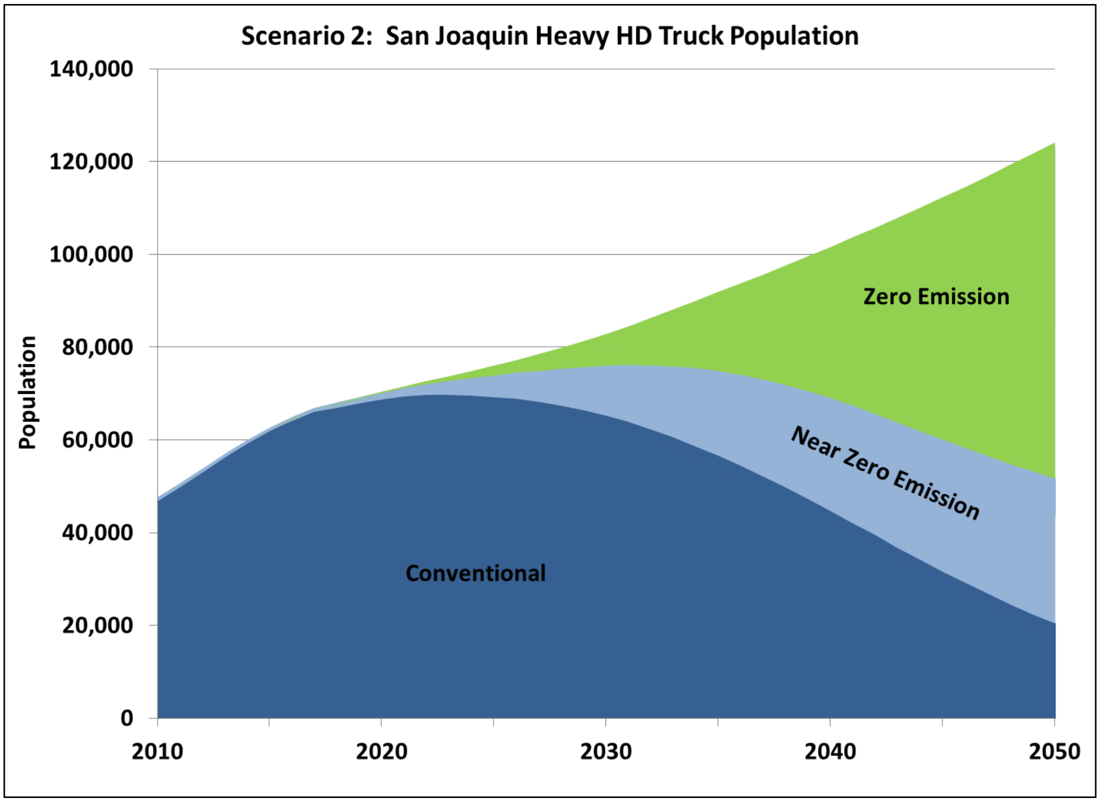

Scenario 2 & 3 - Out-of-State Heavy Duty Truck Sales Fraction
New Vehicle Sales (% Contribution)
100%
80%
60%
40%
20%
0%
2010
2020
2030
2040
2050
Conventional
Near Zero Emission
Zero Emission

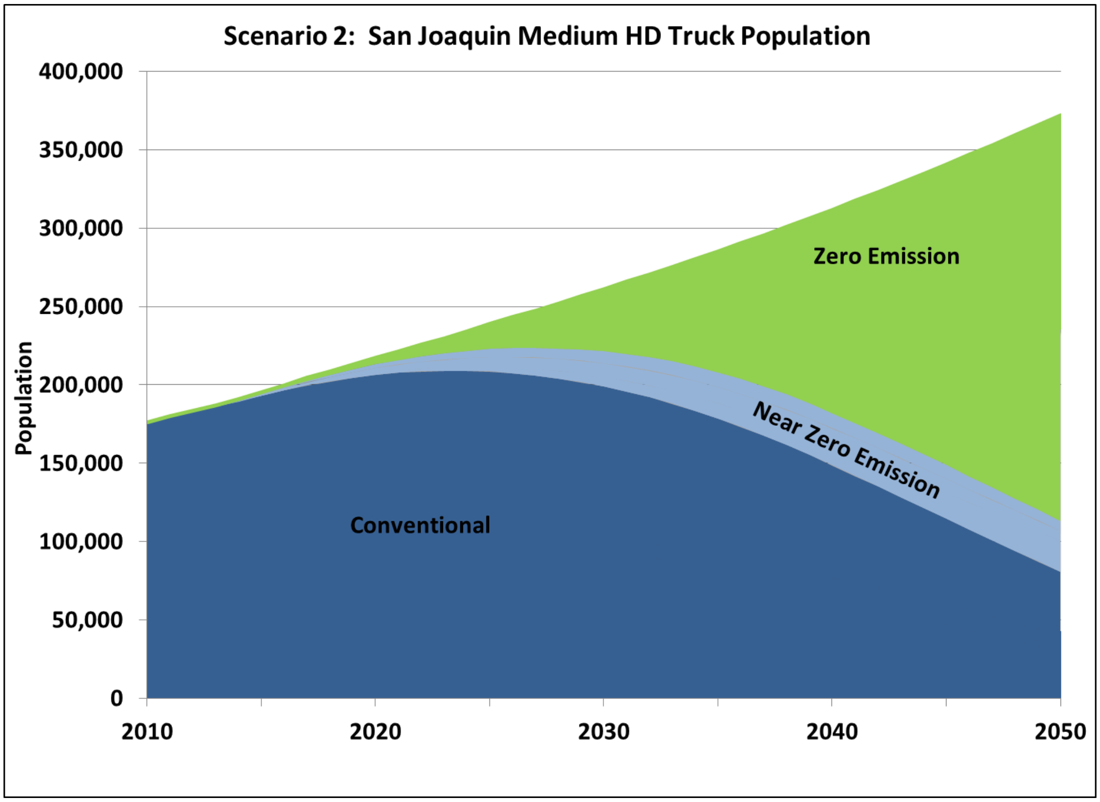

Scenario 2 & 3 - Medium Heavy Duty Truck Sales Fraction
New Vehicle Sales (% Contribution)
100%
80%
60%
40%
20%
0%
2010
2020
2030
2040
2050
Conventional
Zero Emission
Near Zero Emission

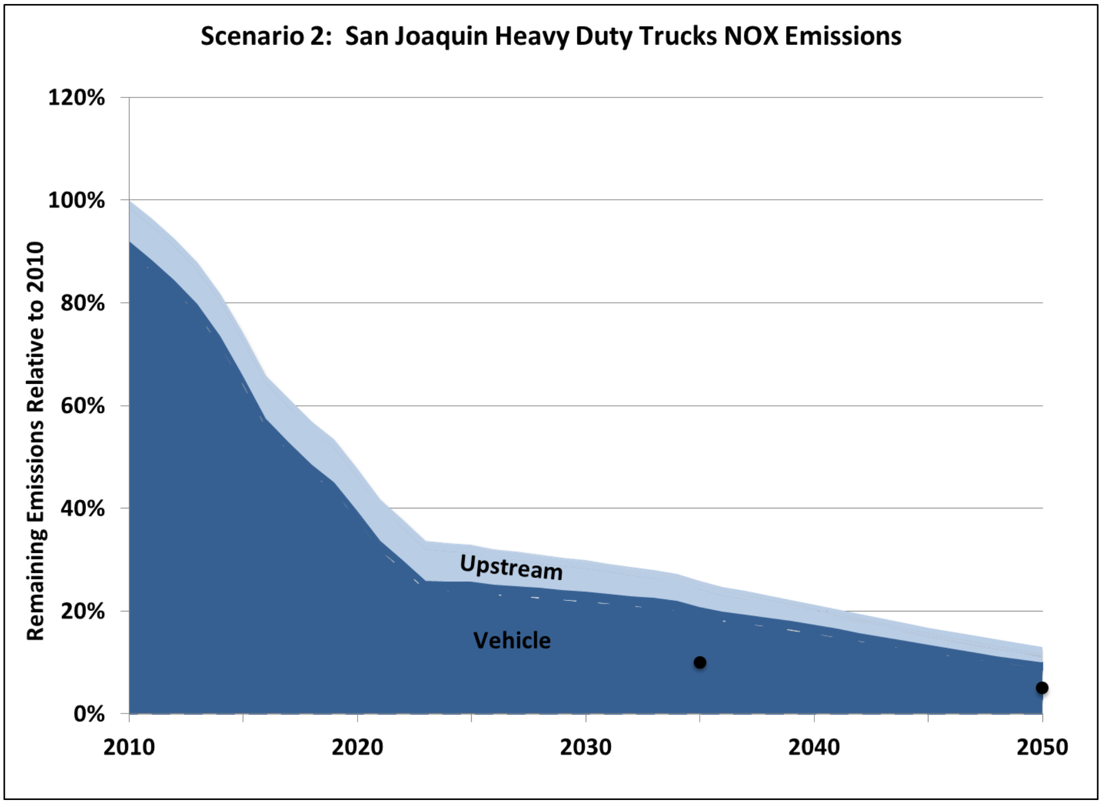

Scenario 2: South Coast Heavy HD Truck Population
Population
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
2010
2020
2030
2040
2050
Zero Emission
Near Zero Emission
Conventional


Scenario 2: South Coast Medium HD Truck Population
Population
900,000
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
2010
2020
2030
2040
2050
Zero Emission
Near Zero Emission
Conventional


Scenario 2: South Coast Heavy Duty Trucks NOX Emissions
Remaining Emissions Relative to 2010
120%
100%
80%
60%
40%
20%
0%
2010
2020
2030
2040
2050
Upstream
Vehicle

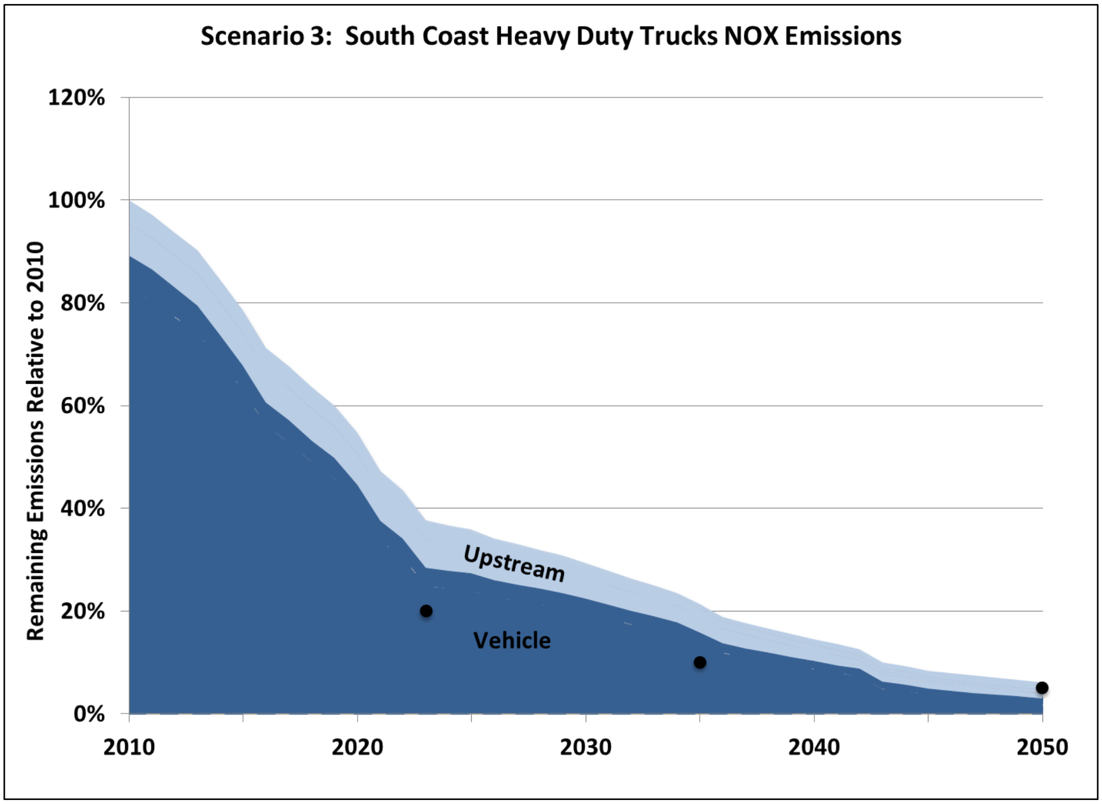

Scenario 2: San Joaquin Heavy HD Truck Population
Population
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
2010
2020
2030
2040
2050
Zero Emission
Near Zero Emission
Conventional

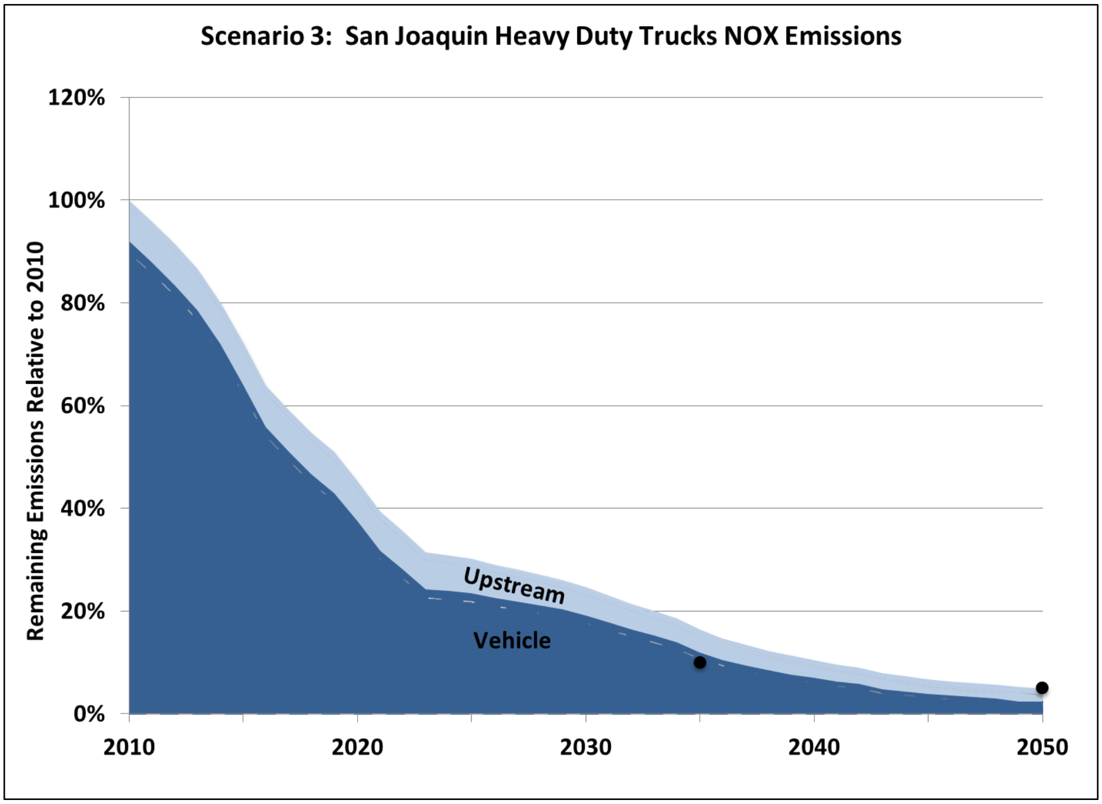

Scenario 2: San Joaquin Medium HD Truck Population
Population
400,000
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
2010
2020
2030
2040
2050
Zero Emission
Near Zero Emission
Conventional


Scenario 2: San Joaquin Heavy Duty Trucks NOX Emissions
Remaining Emissions Relative to 2010
120%
100%
80%
60%
40%
20%
0%
2010
2020
2030
2040
2050
Upstream
Vehicle

Scenario 3:
This scenario is described in the June 27, 2012 Public Review Draft as the advanced technology scenario. The following additional assumptions were made beyond Scenario 2:

- A hypothetical new engine NOx standard was assumed to begin in 2025 with levels 80 percent below the current California standard (a new level of 0.04 gNOx/mi). This was applied to all new conventional (diesel and natural gas) engines sold in California.
- A 20 percent reduced growth in projected truck activity from the 2050 levels was phased in linearly, between 2010 and 2050.

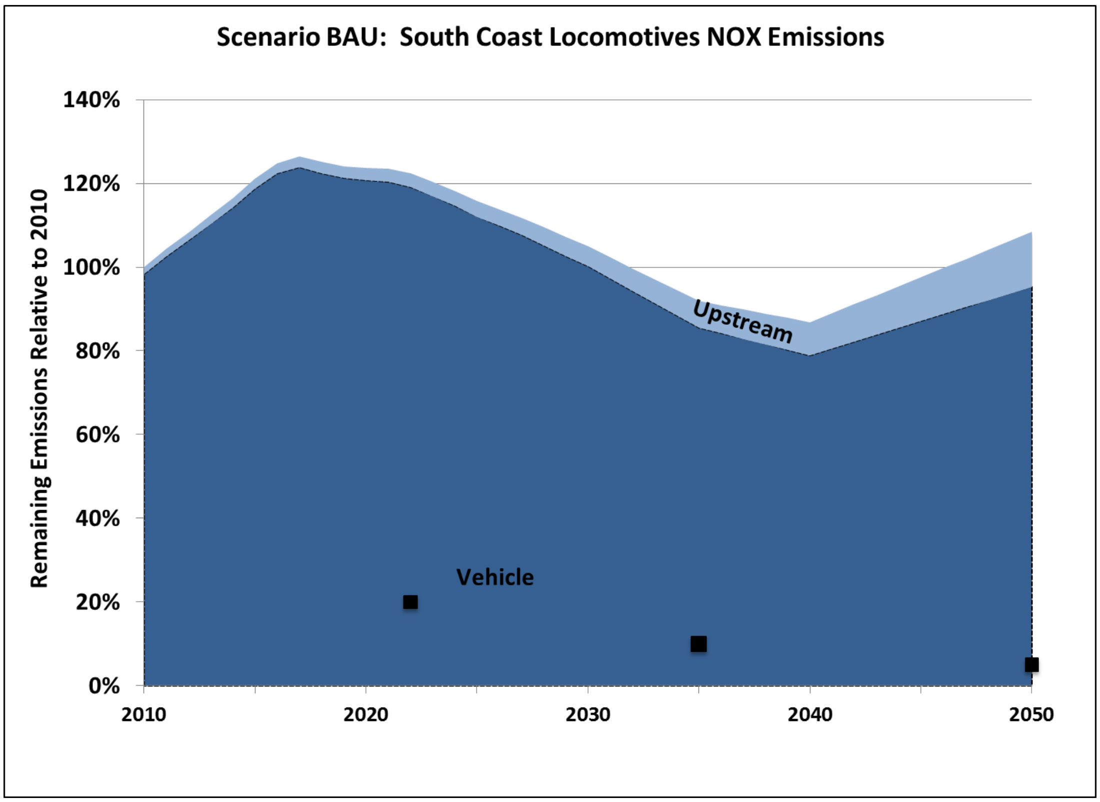


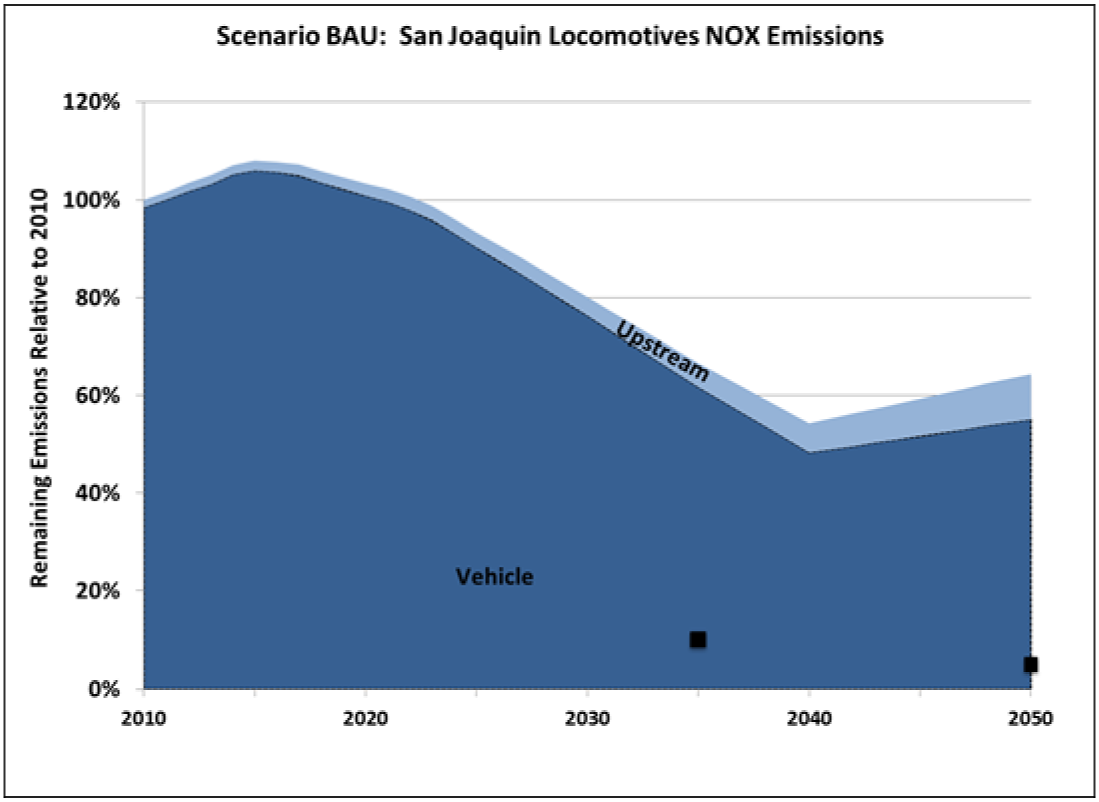

Scenario 3: San Joaquin Heavy Duty Trucks NOX Emissions
Remaining Emissions Relative to 2010
120%
100%
80%
60%
40%
20%
0%
2010
2020
2030
2040
2050
Upstream
Vehicle

Freight and Passenger Locomotives

ARB's emission inventory currently projects an annual increase in line haul locomotive fuel consumption between 2010 and 2035 of 3.3 percent for California, 3.2 percent for South Coast, and 2.7 percent for San Joaquin Valley. This inventory accounts for the annual increase in fuel efficiency through 2035 based on historical data provided by the Association of American Railroads. It is the combined activity growth offset by improving fuel efficiency that yields these estimates. For this vision exercise, staff assumes growth and efficiency improvements continue at these same annual rates between 2035 and 2050.

<u>Scenario 1</u>: This scenario reflects the programs currently being implemented as well as adopted regulations and standards with future implementation dates.





Scenario 2: This scenario, called the accelerated Tier 4 scenario in the June 27, 2012 Public Review Draft, assumes accelerated deployment of federal Tier 4 engines, development and introduction of hybrid locomotives capable of zero-emission track miles, and electrification of the locomotive fleet. It does not assume the promulgation of cleaner, Tier 5 locomotive engine standards by U.S. EPA. The accelerated turn over and hybridization parts of the scenario would be implemented statewide, but the grid-based electrification part of the scenario is focused in the South Coast only. The scenario assumes:

- Accelerated deployment of Tier 4 engines starting in 2015 through 2025 at a rate such that fifty percent of the fleet operating in California (by activity) meets a Tier 4 standard by 2025.

- Accelerated introduction of Tier 4/battery hybrid locomotives starting in 2025. It is assumed that a battery hybrid Tier 4 locomotive is capable of operating 30 percent of its duty cycle in zero-emission model in early model years. The fraction of zero-emission operation gradually grows from 30 percent in 2025 to 45 percent by 2040 through advances in battery technology and optimization of hybrid systems. From 2025 forward, it is assumed that all new purchases are Tier 4/battery hybrid locomotives; no conventional, non-hybridized locomotives are sold after 2024.

  The scenario assumes an accelerated deployment of Tier 4/battery hybrid locomotives statewide such that the following milestones would be met:

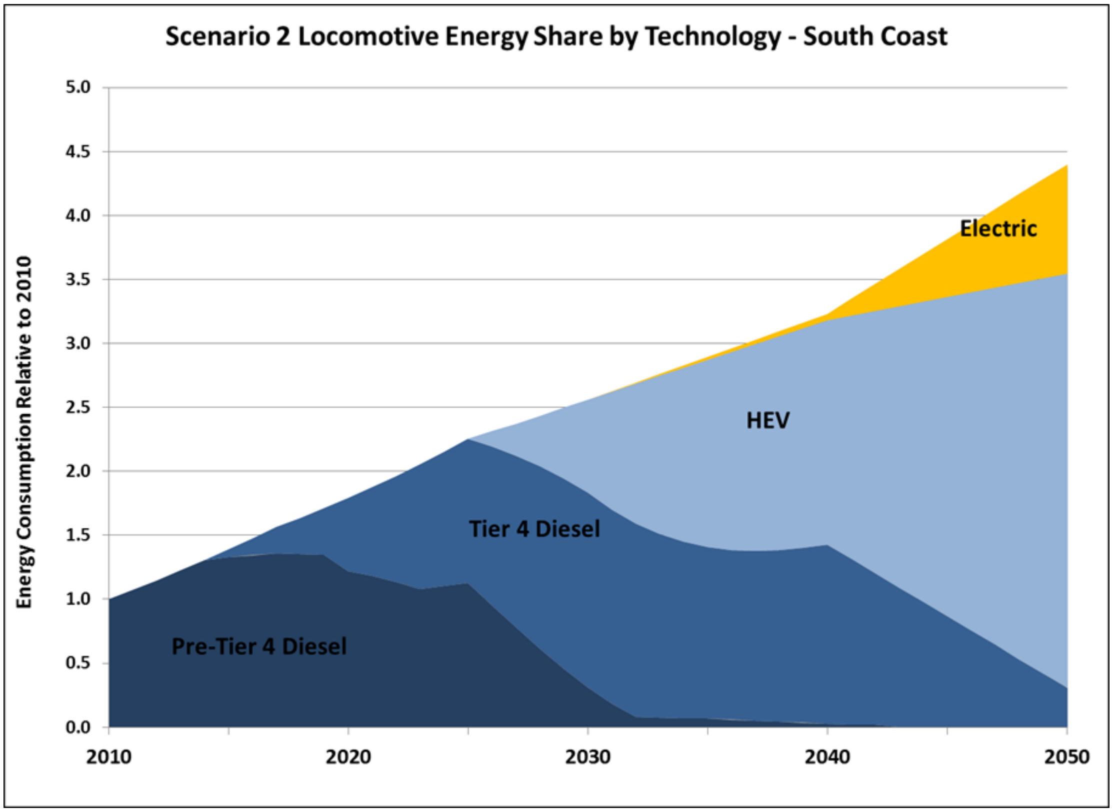
- Ninety five percent of the fleet operating in California is either a Tier 4 or a Tier 4/battery hybrid by 2032. The remaining five percent of the fleet would be pre-Tier 4 for operational flexibility in recognition of the interstate nature of railroad industry.

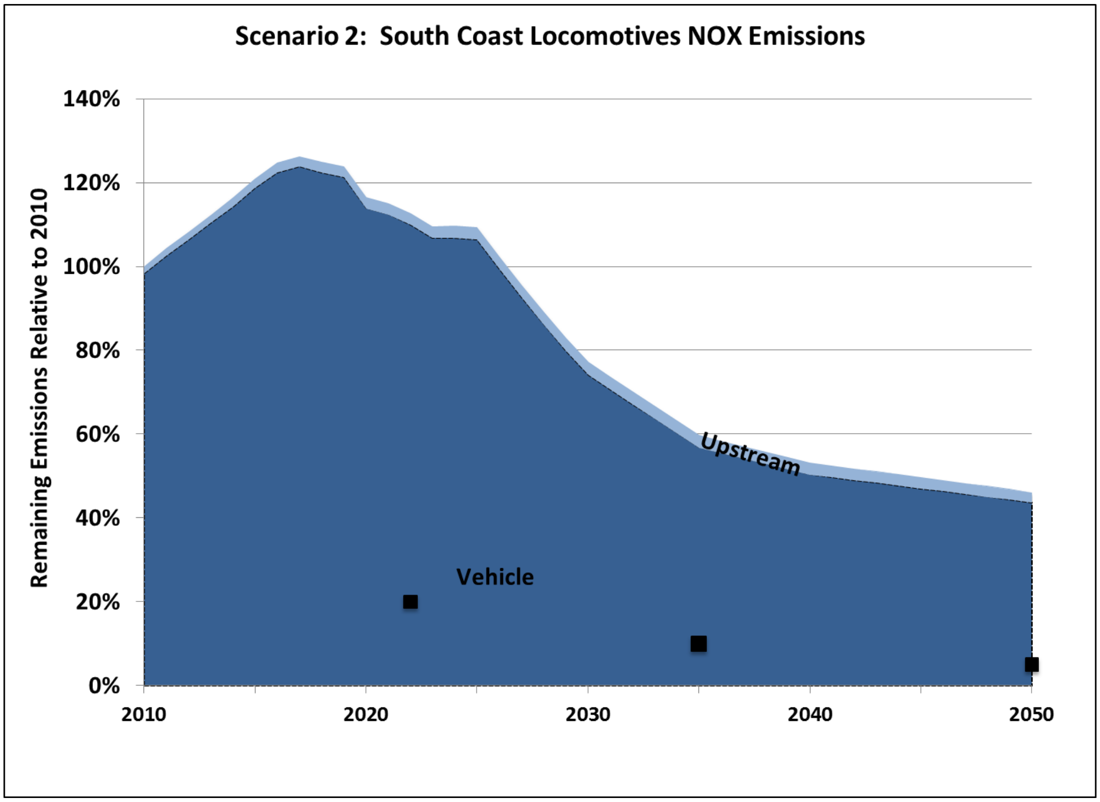
- Ninety five percent of the fleet operating in California is a Tier 4/battery hybrid (or grid-based advanced technology in the South Coast) by 2050. The remaining five percent of the fleet would be Tier 4 for operational flexibility in recognition of the interstate nature of railroad industry.

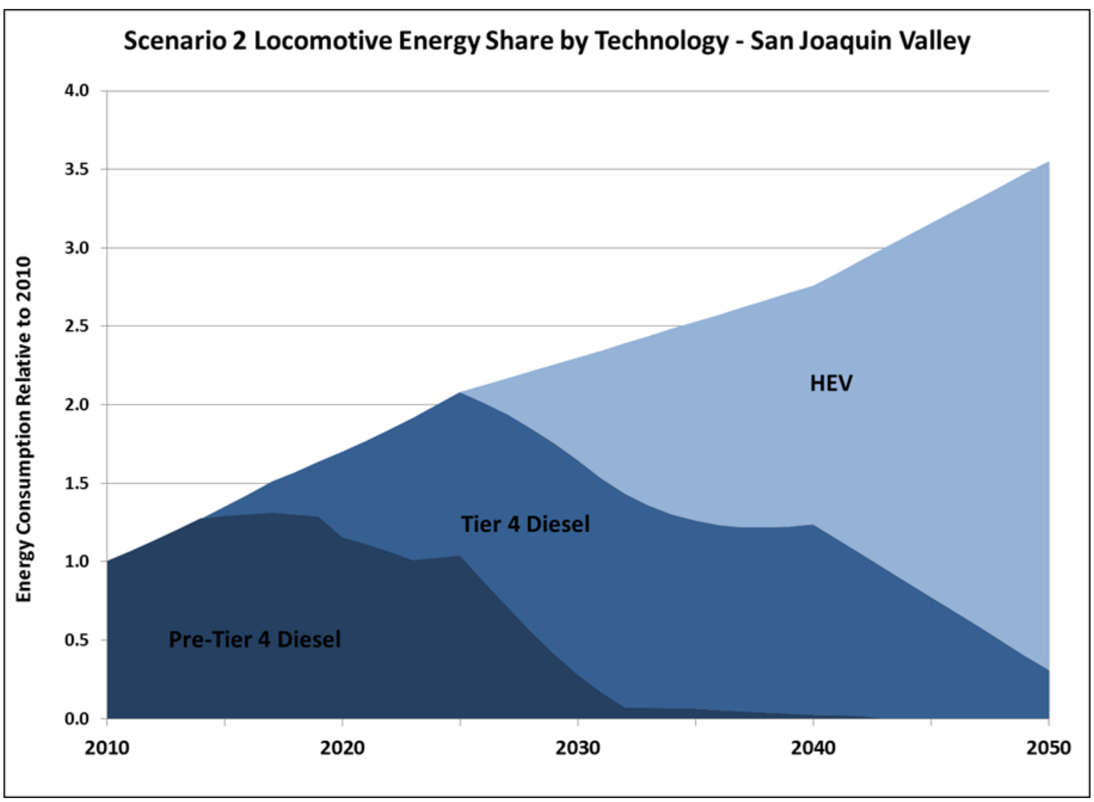
• Development and introduction of advanced grid-based technologies in the South Coast to extend zero emission miles in the post 2035 to 2050 time frame. These could include battery tender cars with grid based charging or some use of wayside power. Staff is not identifying a specific technology other than to assume that it is powered with electricity from the grid. For this scenario, staff assumes:

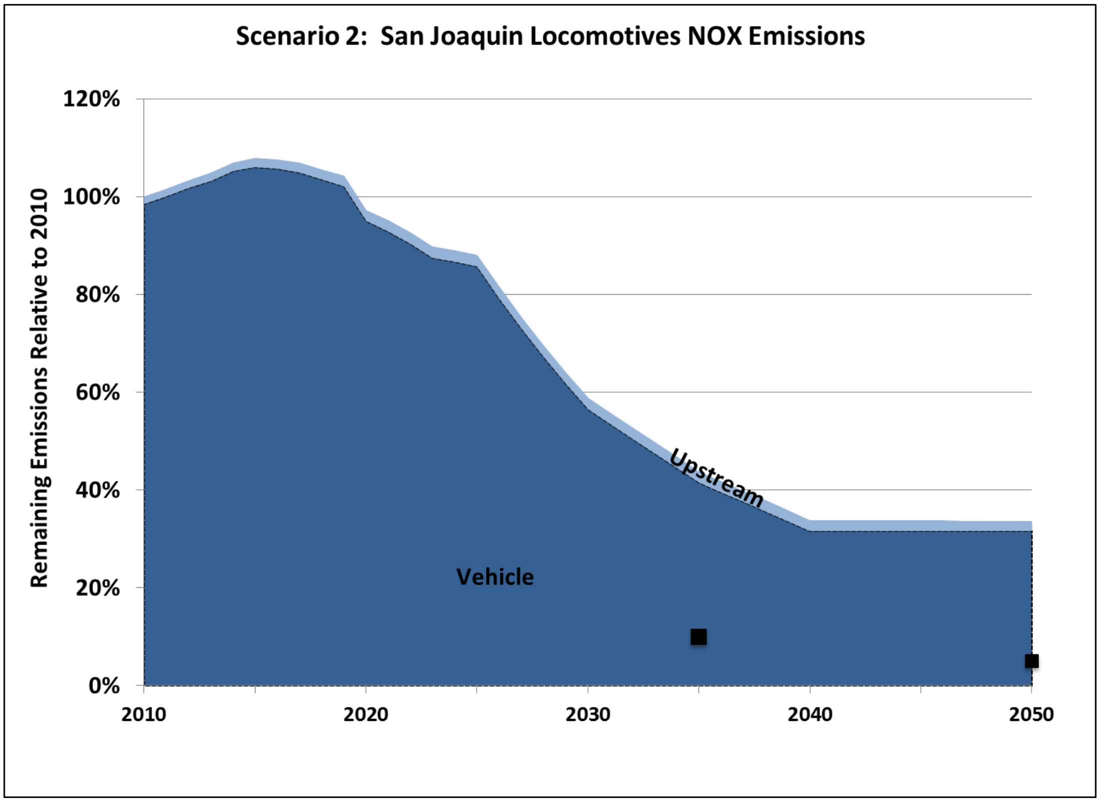
- Two percent of the locomotive activity in the South Coast is powered by grid-based electricity in 2040.

- Twenty percent of the locomotive activity in the South Coast is powered by grid-based electricity in 2050 (with linear growth the fraction of grid-based activity between 2040 and 2050).




Scenario 2: South Coast Locomotives NOX Emissions
Remaining Emissions Relative to 2010
140%
120%
100%
80%
60%
40%
20%
0%
2010
2020
2030
2040
2050
Upstream
Vehicle


Scenario 2 Locomotive Energy Share by Technology - San Joaquin Valley
Energy Consumption Relative to 2010
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
2010
2020
2030
2040
2050
HEV
Tier 4 Diesel
Pre-Tier 4 Diesel



Scenario 3: This scenario builds upon Scenario 2 described above (accelerated introduction of Tier 4 engines plus hybridization plus electrification), but it also assumes the introduction of a Tier 5 standard starting in 2025. Tier 5 NOx emissions are assumed to be 75 percent lower than Tier 4 levels (and hence, about 94 percent lower than today's Tier 2 locomotive fleet average in the South Coast). The Tier 5 standard is implemented in conjunction with hybridization, so non-hybridized Tier 5 engines are not part of this scenario. This scenario also assumes a small reduction in growth/activity. Similar to Scenario 2, the accelerated turn over, hybridization, and activity parts of the scenario would be implemented statewide, but the grid-based electrification part of the scenario is focused in the South Coast only. The scenario assumes:

- Accelerated deployment of Tier 4 engines starting in 2015 through 2025 at a rate such that fifty percent of the fleet operating in California (by activity) meets a Tier 4 standard by 2025.

- Accelerated introduction of Tier 5/battery hybrid locomotives starting in 2025. For this scenario, all Tier 5 engines are introduced with a battery hybrid configuration. Non-hybridized Tier 5 engines are not part of this scenario.

  It is assumed that a battery hybrid Tier 5 locomotive is capable of operating 30 percent of its duty cycle in zero-emission model in early model years. The fraction of zero-emission operation gradually grows from thirty percent in 2025 to 45 percent by 2040 through advances in battery technology and optimization of hybrid systems. From 2025 forward, it is assumed that all new purchases are Tier 5/battery hybrid locomotives.

The scenario assumes an accelerated deployment of Tier 5/battery locomotives statewide such that the following milestones would be met:

- Ninety five percent of the fleet operating in California is either a Tier 4 or a Tier 5/battery hybrid by 2032. The remaining five percent of the fleet would be pre-Tier 4 for operational flexibility in recognition of the interstate nature of railroad industry.

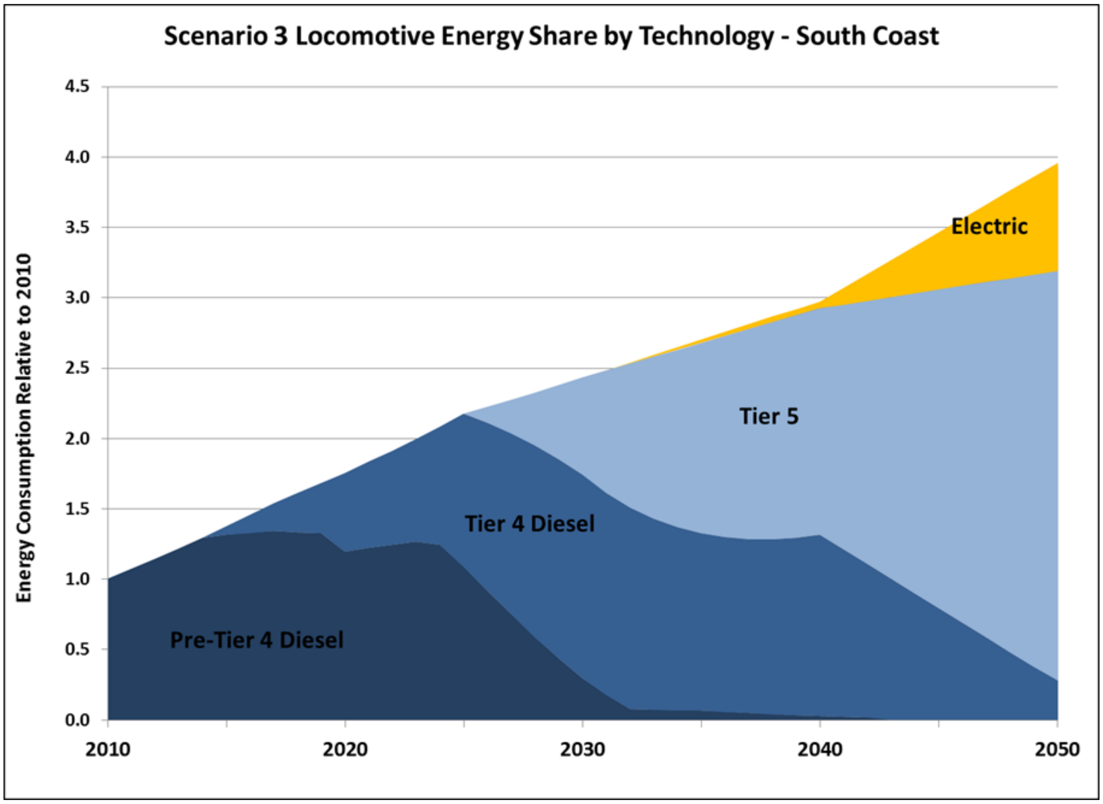
- Ninety five percent of the fleet operating in California is a Tier 5/battery hybrid (or grid-based advanced technology in the South Coast) by 2050. The remaining five percent of the fleet would be Tier 4 for operational flexibility in recognition of the interstate nature of railroad industry.

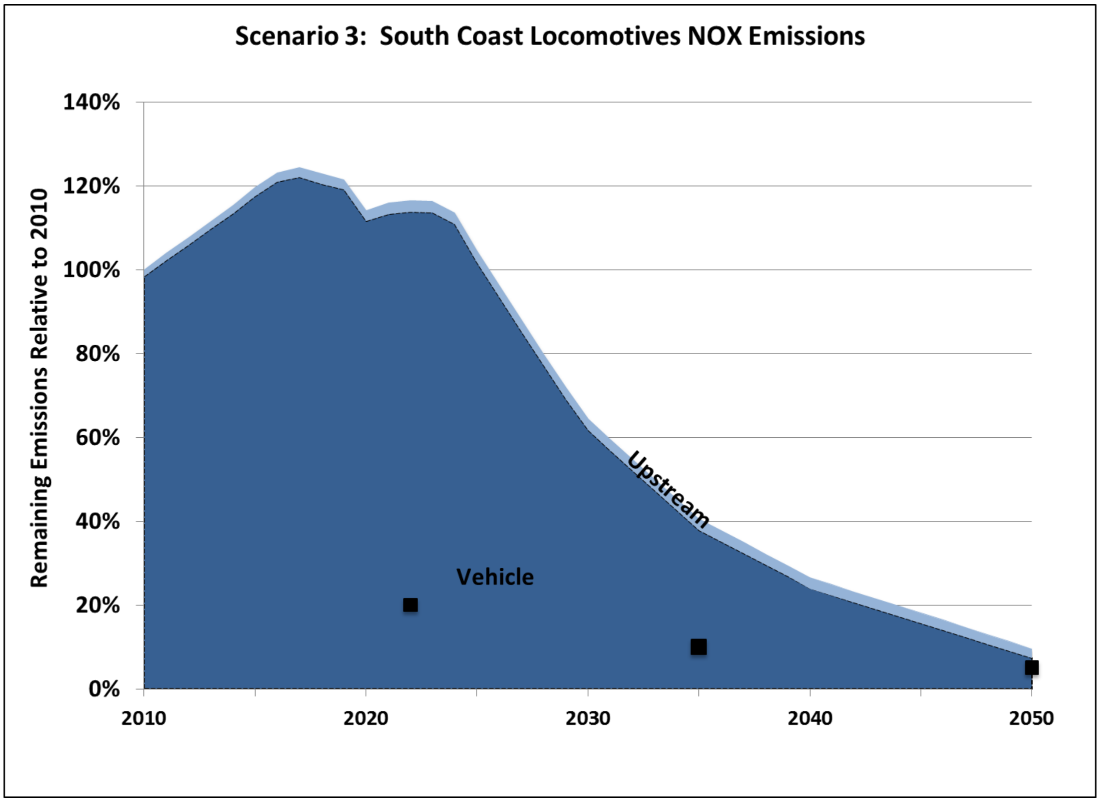
- Development and introduction of advanced grid-based technologies in the South Coast to extend zero emission miles in the post 2035 to 2050 time frame. These could include battery tender cars with grid based charging or some use of wayside power. Staff has not identified a specific technology other than to assume that it is powered with electricity from the grid. For this scenario, staff assumes:

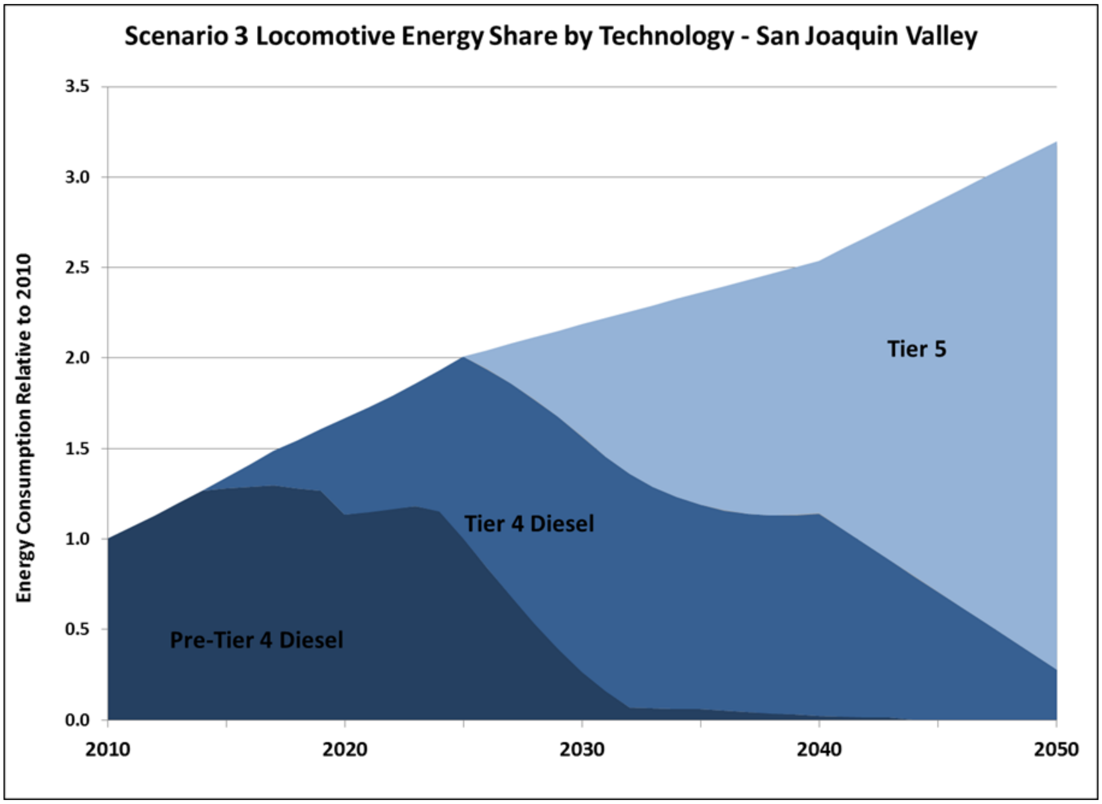
  - Two percent of the locomotive activity in the South Coast is powered by grid-based electricity in 2040.

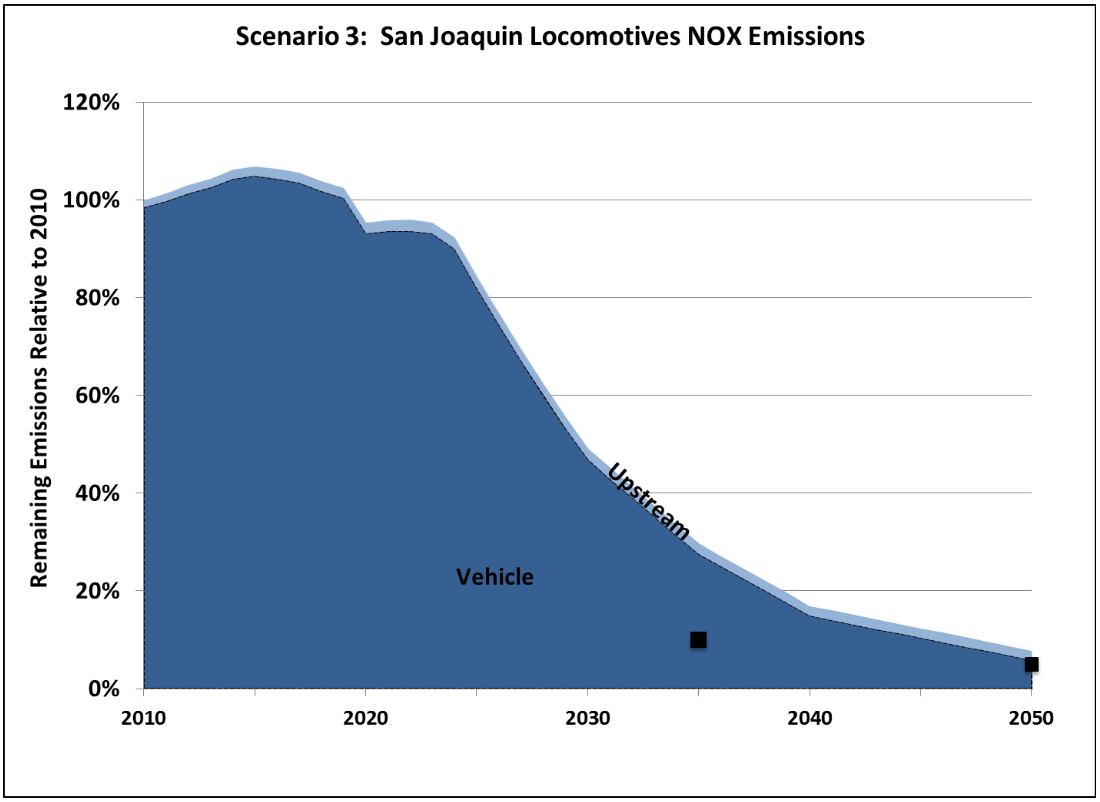
  - Twenty percent of the locomotive activity in the South Coast is powered by grid-based electricity in 2050 (with linear growth the fraction of grid-based activity between 2040 and 2050).

- This scenario assumes a small reduction in activity growth relative to scenarios 1 and 2 such that overall activity is ten percent less by 2050 than in scenarios 1 and 2.


Scenario 3 Locomotive Energy Share by Technology - South Coast
Energy Consumption Relative to 2010
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
2010
2020
2030
2040
2050
Electric
Tier 5
Tier 4 Diesel
Pre-Tier 4 Diesel


Scenario 3: South Coast Locomotives NOX Emissions
Remaining Emissions Relative to 2010
140%
120%
100%
80%
60%
40%
20%
0%
2010
2020
2030
2040
2050
Upstream
Vehicle

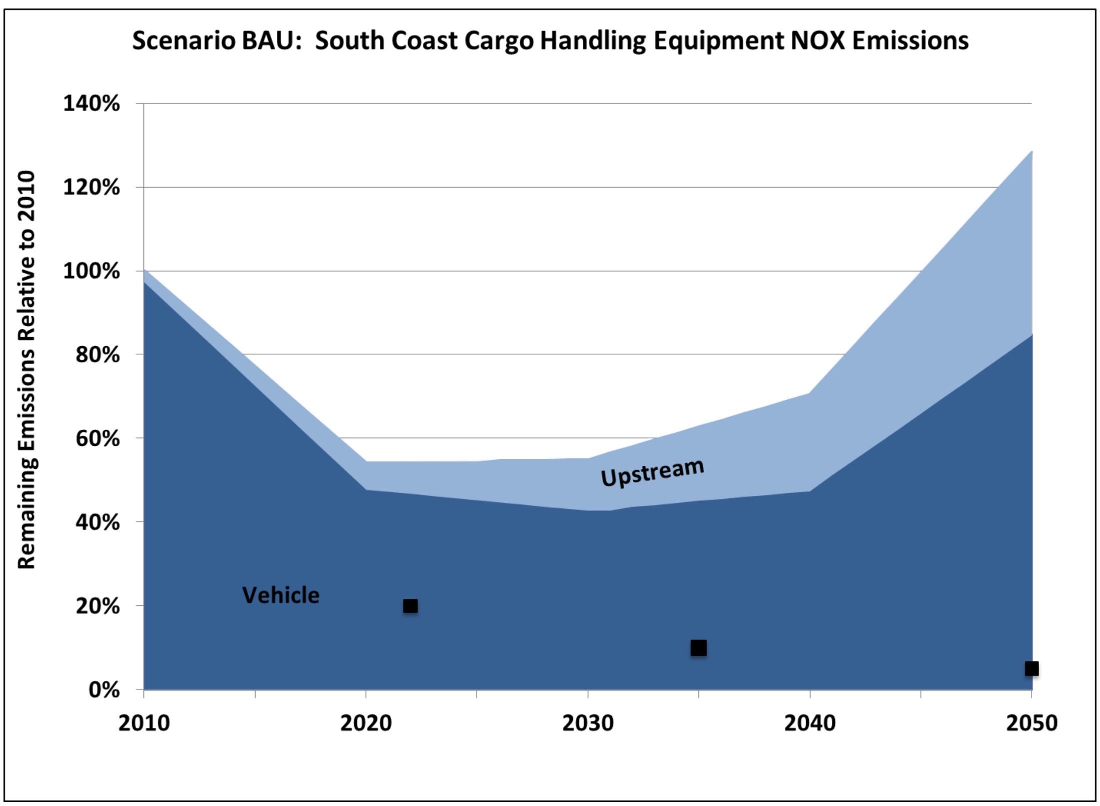

Scenario 3 Locomotive Energy Share by Technology - San Joaquin Valley
Energy Consumption Relative to 2010
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
2010
2020
2030
2040
2050
Tier 5
Tier 4 Diesel
Pre-Tier 4 Diesel

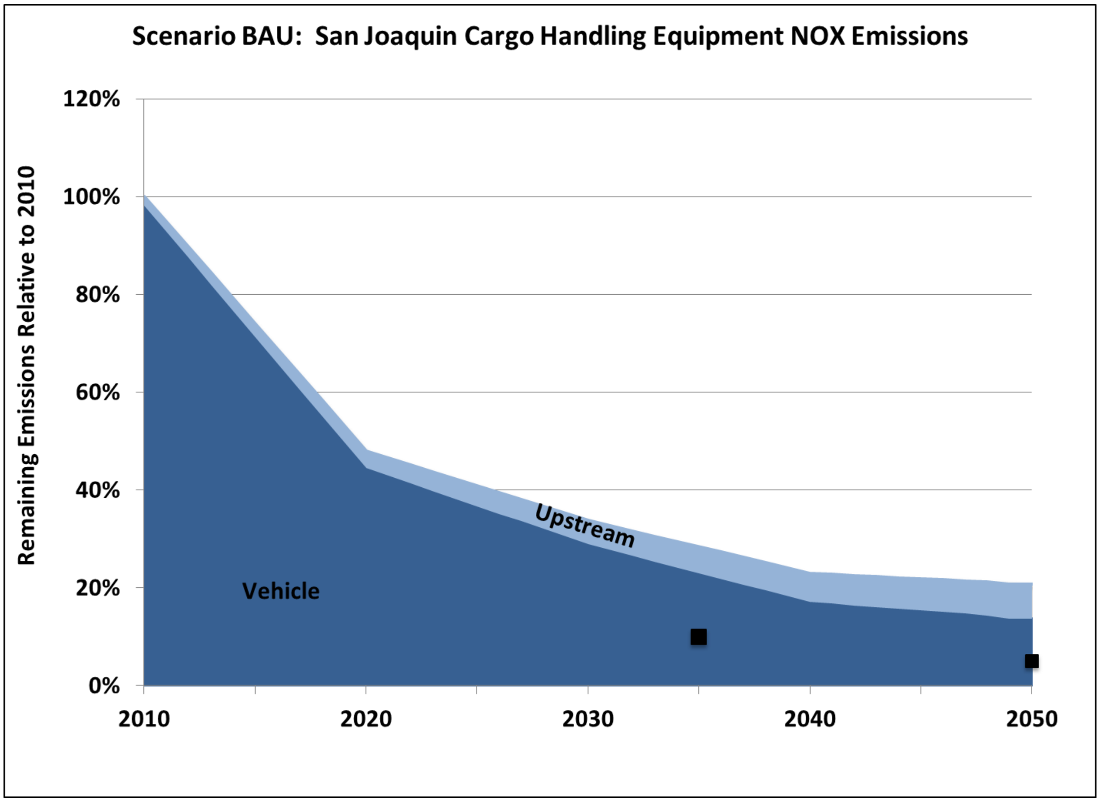

Scenario 3: San Joaquin Locomotives NOX Emissions
Remaining Emissions Relative to 2010
120%
100%
80%
60%
40%
20%
0%
2010
2020
2030
2040
2050
Upstream
Vehicle

Cargo Handling Equipment

The regulation for Mobile Cargo Handling Equipment at Ports and Intermodal Rail Yards (CHE Regulation), which became effective on December 31, 2006, requires the best available control technology for both in-use (equipment in fleets as of January 1, 2007) and new equipment. This means that all in-use equipment must be either retrofitted with highest level verified diesel emission control technology or replaced with engines meeting the U.S. EPA new engine standards. All new engines purchased must meet the U.S. EPA new engine standards and retrofitted with highest level verified diesel emission control technology if not a Tier 4 engine. The following scenarios assumed that all in-use equipment would either be retrofitted or replaced and all new equipment purchased would be the cleanest and most technically advanced.

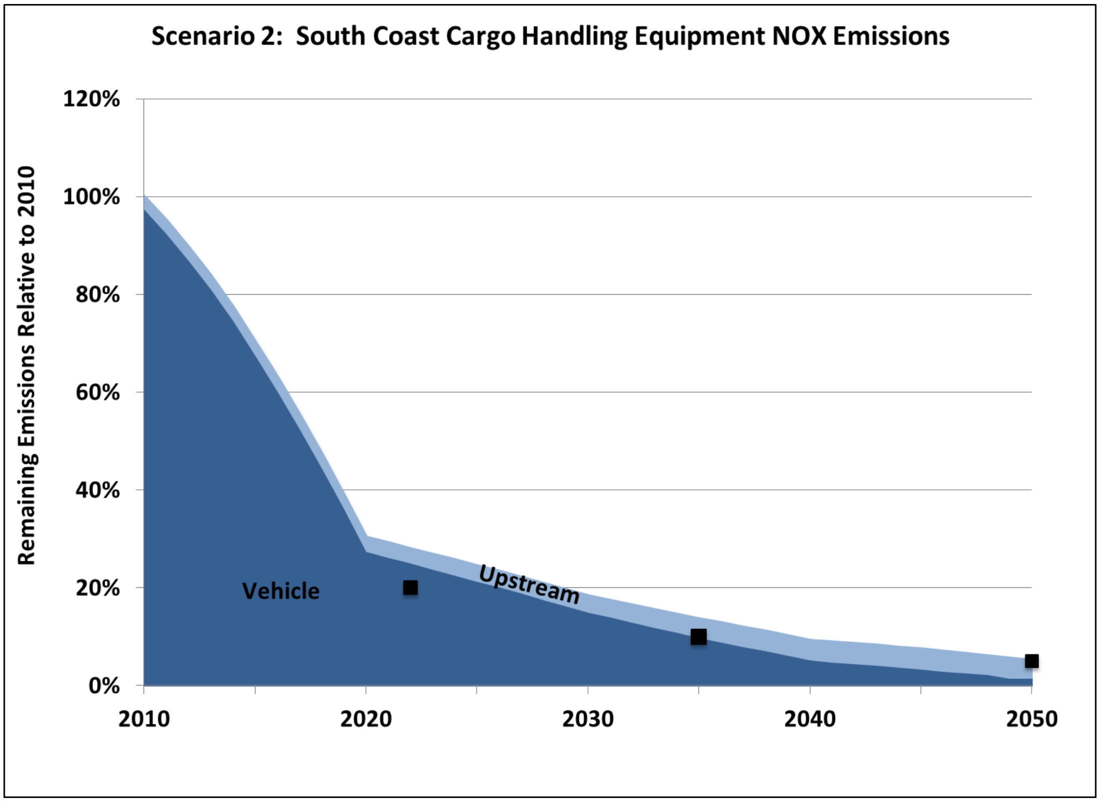
Scenario 1: On September 22, 2011, the Air Resources Board approved amendments to the CHE Regulation. These amendments made some clarifications to the regulatory language and added more flexibility to the compliance options. The BAU scenario used the same inventory that was used for the development of the amendments. This scenario assumed that all existing diesel equipment would be replaced with similar diesel equipment with engines meeting the U.S. EPA new engine standards.

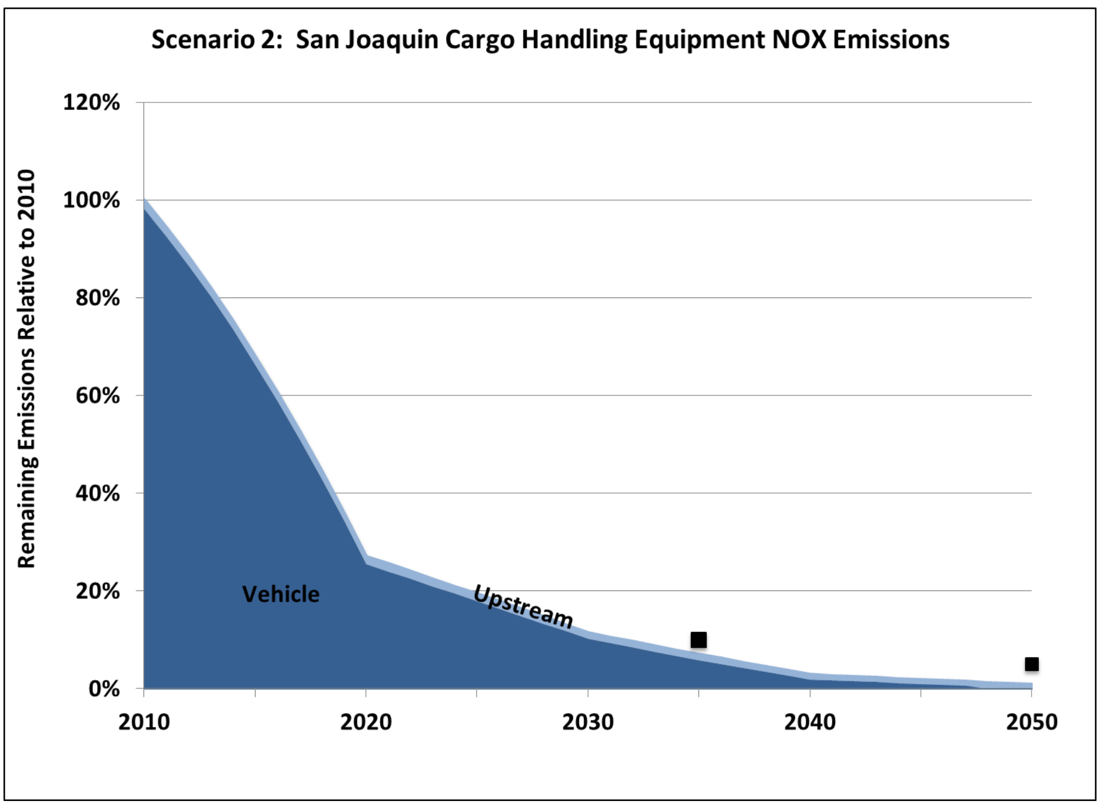




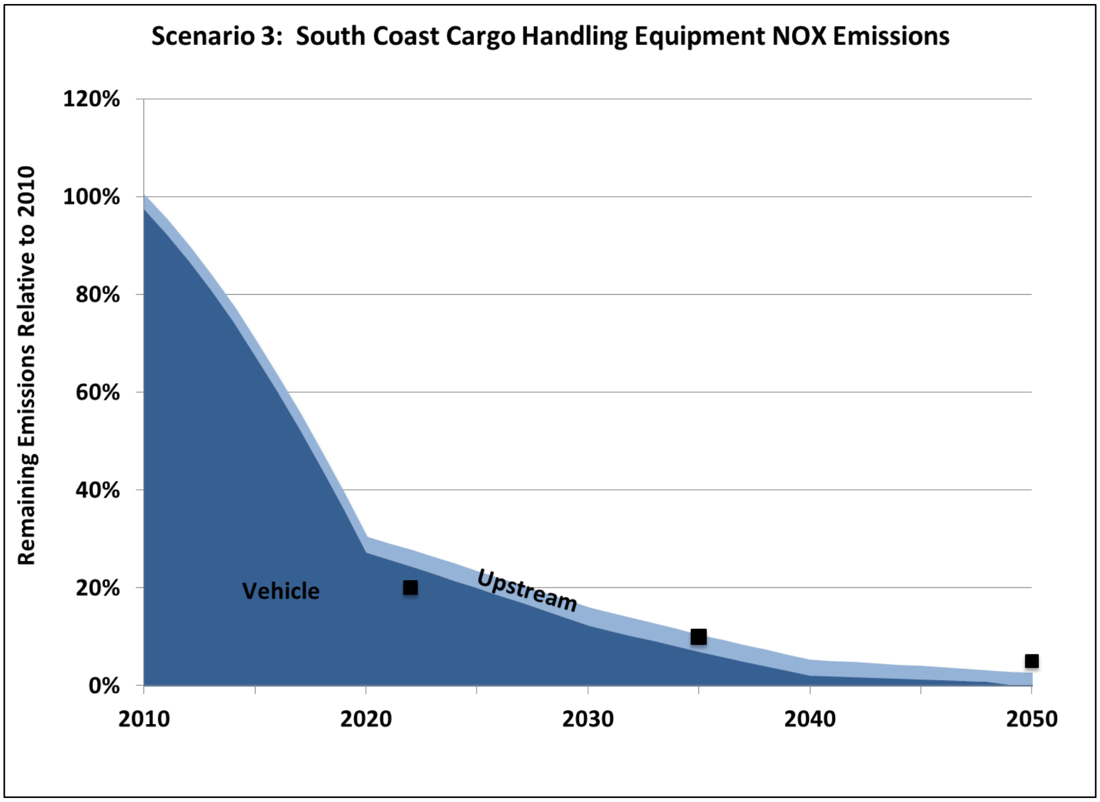
<u>Scenario 2</u>: The results of the BAU scenario showed that the activity growth rate at the port over-powers any emissions benefits achieved by using clean engine technologies. The growth rate at the ports is tied to the growth rate of the ocean-going vessels. For CHE, horsepower-hours increase five percent annually from 2000 to 2030. The activity is projected to grow at five percent per year from 2030 to 2050. In order to bring the CHE emissions down, the second scenario assumed that all CHE categories will transition to electric technology. These technologies include battery electric, electric wayside power, mag lev, and plug-in hybrid.

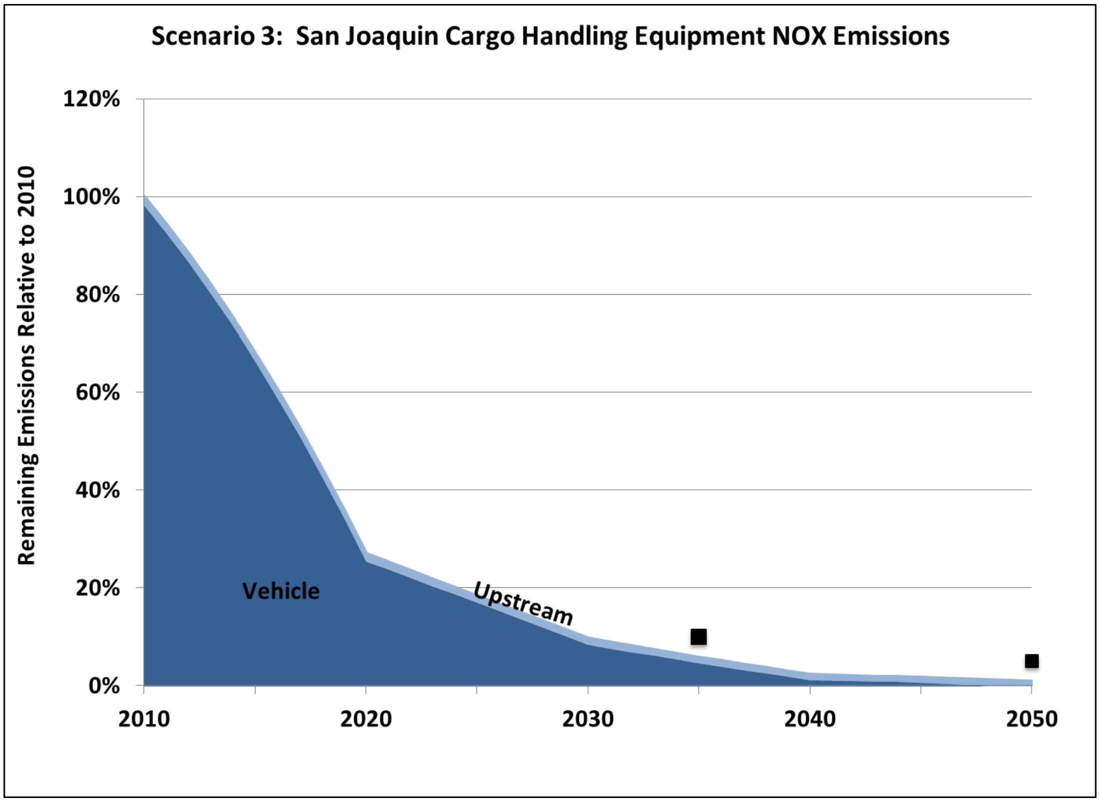
- Market penetration of electric technology was assumed to be 90 percent by 2050 for forklifts and RTG cranes. Phase-in was assumed to be linear, beginning 2020.
- A 45 percent market penetration was assumed for yard trucks.
- To obtain maximum efficiency, staff assumed that port automation in conjunction with mag lev technology would be a viable option. This technology was applied to the remaining percentage of yard trucks and to 90 percent of the container handling equipment.
- For the construction equipment and the other general industrial equipment categories, staff assumed that 10 percent of the equipment will need to continue to use the conventional diesel engine.
- The remaining percentage will be replaced with the diesel-electric hybrids.


Scenario 2: South Coast Cargo Handling Equipment NOX Emissions
Remaining Emissions Relative to 2010
120%
100%
80%
60%
40%
20%
0%
2010
2020
2030
2040
2050
Vehicle
Upstream


Scenario 2: San Joaquin Cargo Handling Equipment NOX Emissions
Remaining Emissions Relative to 2010
120%
100%
80%
60%
40%
20%
0%
2010
2020
2030
2040
2050
Vehicle
Upstream

Scenario 3: For Scenario 3, the penetration rates from Scenario 2 were not changed. It was assumed that a new Tier 5 off-road engine emission standard would be developed that would provide more stringent NOx standards consistent with the off-road equipment assumptions. Market penetration of new Tier 5 off-road engines (assumed to emit 60 percent lower NOx emissions than Tier 4 levels) was assumed to be 62 percent by 2050. For the construction equipment and the other general industrial equipment categories, staff assumed that 10 percent of the equipment will need to continue to use the conventional diesel engine. Phase-in was assumed to be linear, beginning 2020.

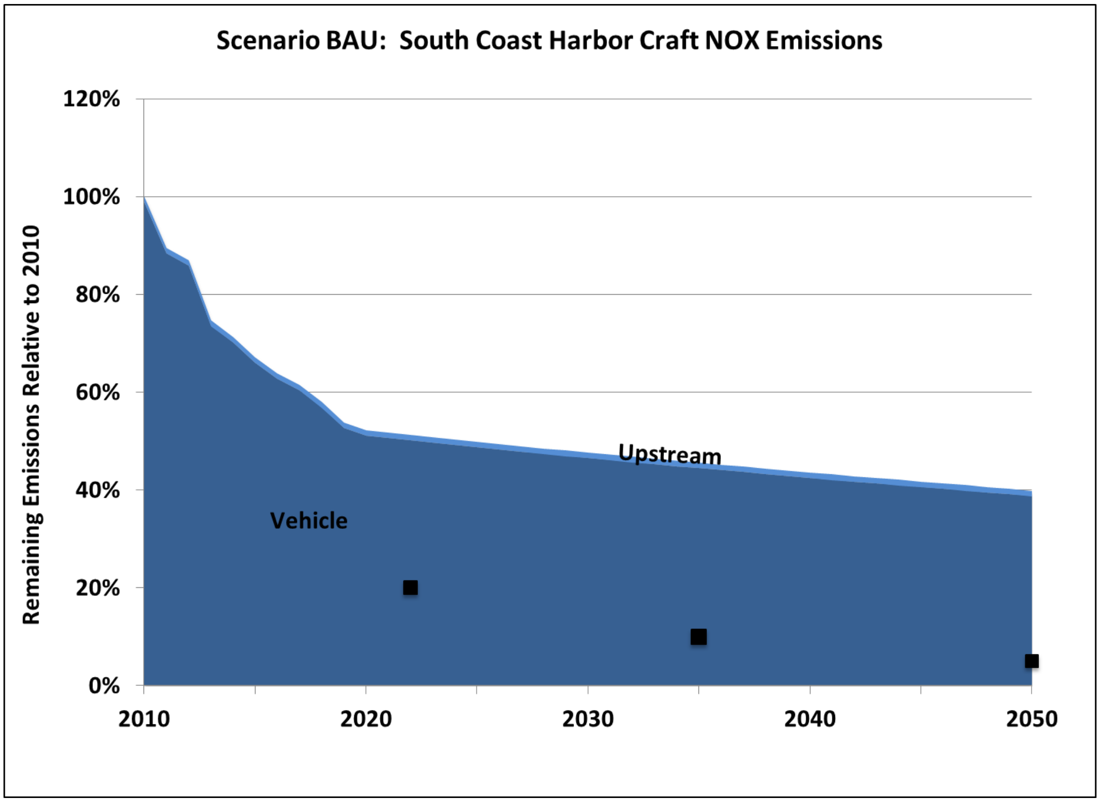



Scenario 3: San Joaquin Cargo Handling Equipment NOX Emissions
Remaining Emissions Relative to 2010
120%
100%
80%
60%
40%
20%
0%
2010
2020
2030
2040
2050
Vehicle
Upstream

Commercial Harbor Craft

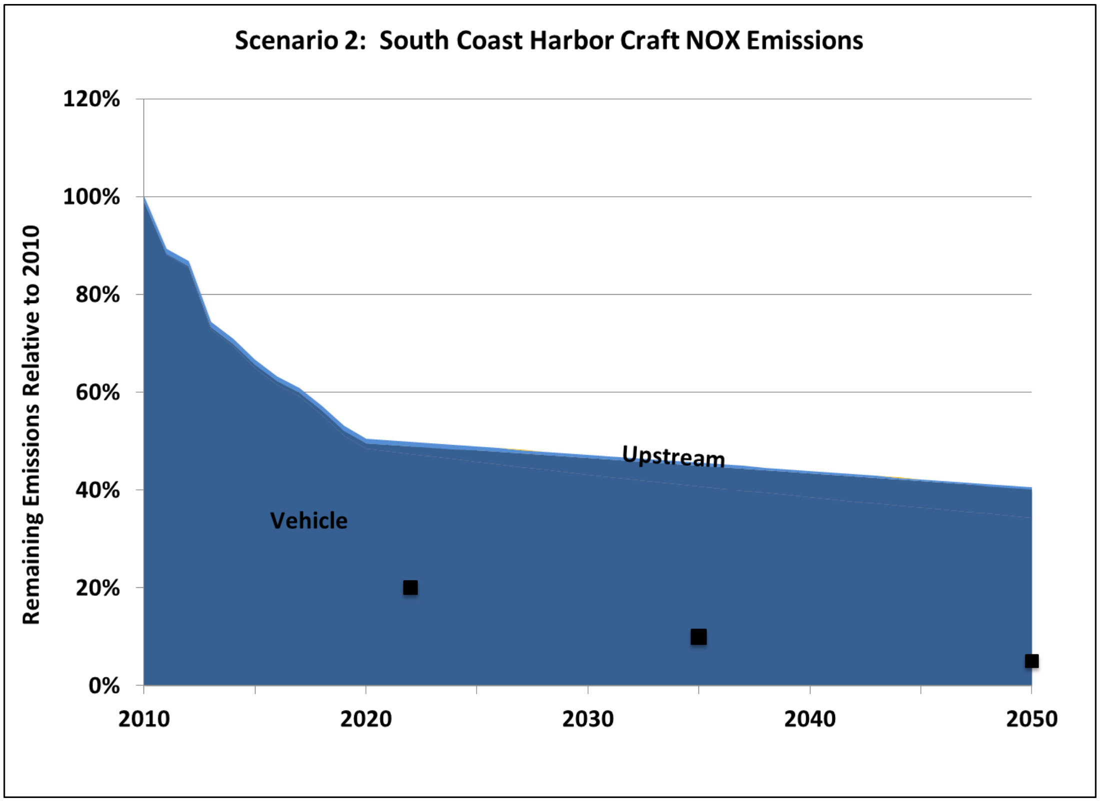
The Commercial Harbor Craft (CHC) regulation was adopted in November 2007 and became effective in January 2009. The CHC regulation includes emission limits for all new engines and for in-use engines on vessels operating in the vessel categories of ferry, excursion, tugboat, towboat, crew and supply, and barge and dredge. Additionally, the regulation has reporting, recordkeeping, and monitoring requirements. The CHC regulation requires engines on all new vessels to meet applicable United States Environmental Protection Agency (U.S. EPA) marine or off-road engine emission standards at the time the vessel is acquired. Replacement engines installed on any in-use CHC are required to meet the Tier 2 or Tier 3 standards in effect at the time of purchase of the engine. In addition, the CHC regulation requires existing Tier 1 and earlier auxiliary and propulsion engines on in-use ferries, excursion vessels, tugboats, and towboats, crew and supply vessels, barges, and dredges to meet U.S. EPA Tier 2 or Tier 3 marine or off-road engine standards in effect at the time compliance is required. There is a phased compliance schedule that requires the dirtiest, highest use engines be brought into compliance first. Additionally, the in-use engine compliance timeline for some vessel-use categories is accelerated by two years for vessels that operate in the South Coast Air Quality Management District to achieve earlier emission reductions needed in that area.

Scenario 1: This scenario reflects the programs currently being implemented as well as adopted regulations and standards with future implementation dates. Additionally, a slow introduction of hybrid technologies was assumed, including both diesel –electric and diesel-alternative energy source hybrids, with the majority of the fleet remaining conventional diesel.



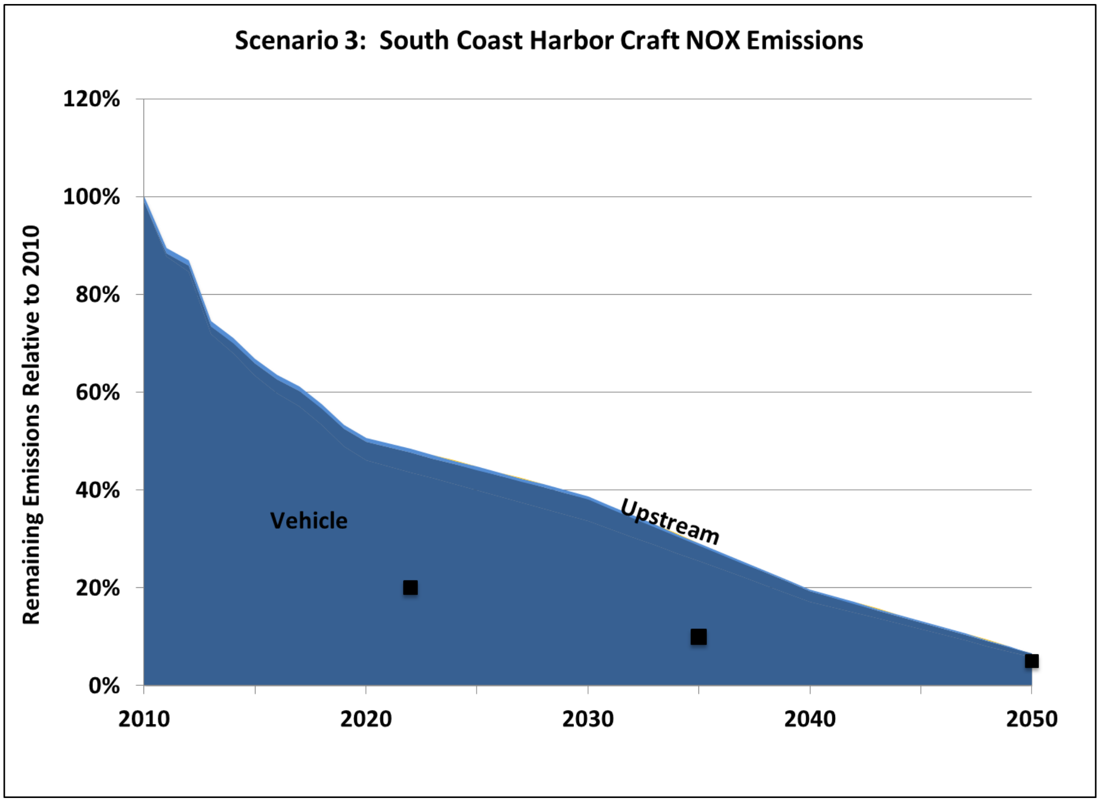
Scenario 2:

- This scenario assumes accelerated hybridization of CHC vessels, using alternative technologies such as wind, solar, and shore power, with deployment levels of about 20 percent of the fleet in 2030 and 42 percent in 2050.
- Diesel-electric hybrids were estimated to be 14 percent of the fleet in 2030 and 28 percent in 2050.
- LNG is assumed to play a larger part initially with about 20 percent of the fleet going to this alternative fuel in 2020 but dropping to 5 percent due to replacement with other alternative technologies, primarily hybrids, in 2050.
- Similarly, battery electric was assumed to play a small role with market penetration of less than 10 percent throughout the evaluated time period.



Scenario 3: This scenario assumes a slightly more accelerated introduction of alternative technologies. The scenario assumes:

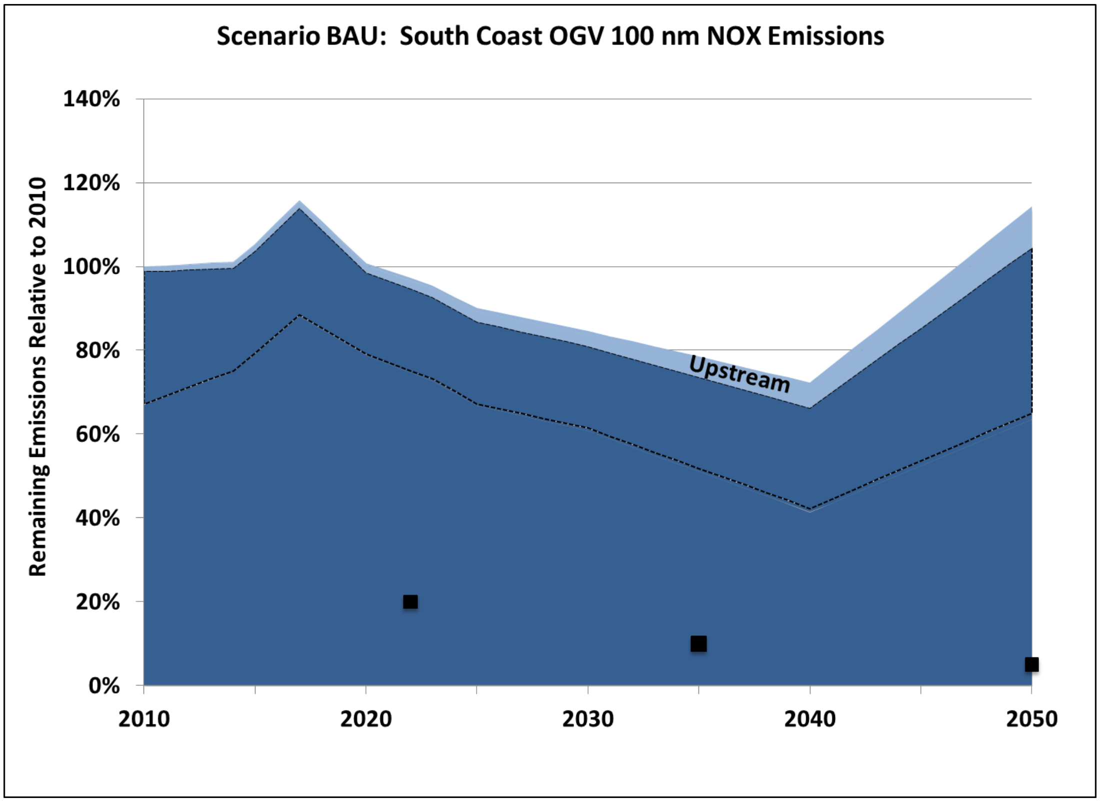
- Accelerated introduction of hybrid technologies, including alternative energy sources such as wind and solar, with market penetrations of 25 percent in 2030 and 45 percent in 2050.
- Market penetration for diesel electric technologies of 14 percent in 2030 and 30 percent in 2050.
- Alternative fuels, primarily LNG, with about 10 percent market penetration through the 2030 and 2050 time frame.
- While the standards for marine engines lag those for off-road engines in timing and the Tier 4 standard applies only to the largest marine engines, those over 800 hp, it is anticipated that, similar to the off-road standards, a Tier 5 standard will be developed for these largest marine engines, which would achieve both a significant efficiency increase and additional NOx reductions.

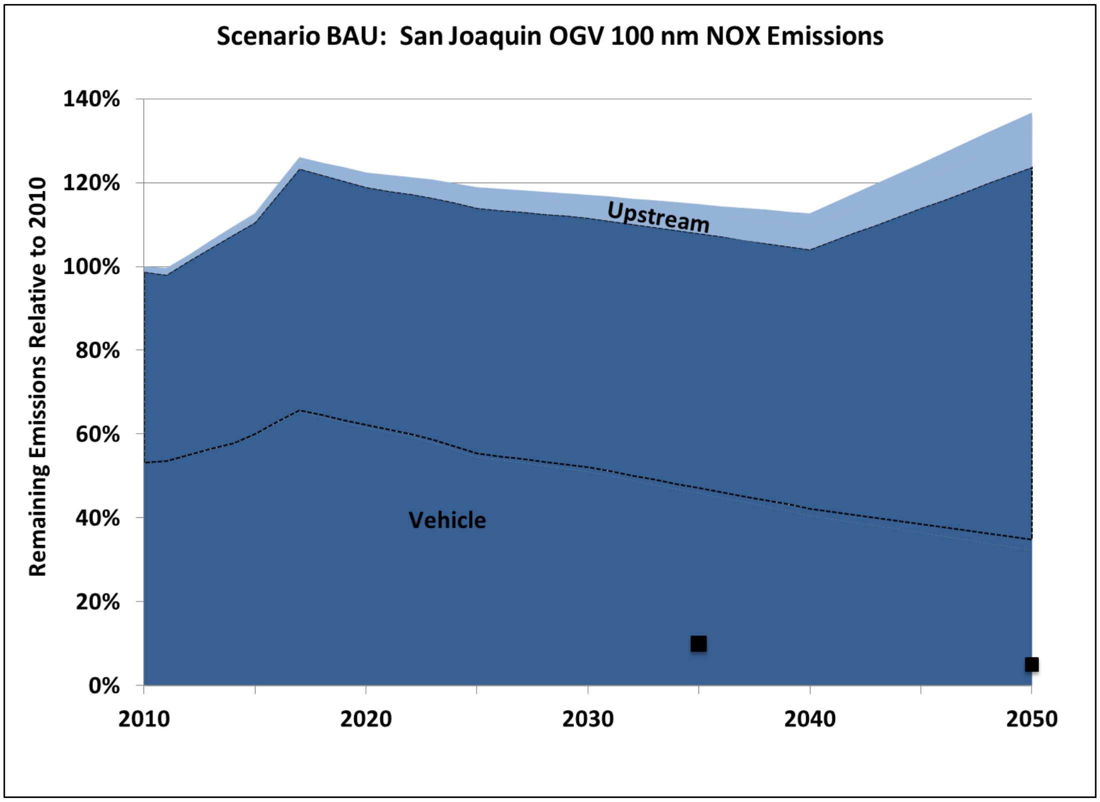

Scenario 3: South Coast Harbor Craft NOX Emissions
Remaining Emissions Relative to 2010
120%
100%
80%
60%
40%
20%
0%
2010
2020
2030
2040
2050
Vehicle
Upstream

Commercial Ships (Ocean Going Vessel)

For ocean-going vessels (OGVs) staff developed a set of assumptions for three scenarios. The assumptions for each of these three scenarios are described below:

Scenario 1: This scenario reflects the programs currently being implemented as well as adopted regulations and standards with future implementation dates.





Scenario 2: The next scenario investigated for OGVs relied on aggressive assumptions regarding the potential strategies that might be employed to reduce emissions and the carbon footprint from OGV.

Growth Rate

The growth rate assumption for OGVs is consistent with those used in the current statewide emissions inventory methodology for OGV, assuming about a 5 percent growth rate per year between 2020 and 2050.

Transiting- New OGVs

- Improved Efficiency Requirements (EEDI):
  Increased efficiency index will provide emissions reductions of 10 percent, 20 percent, and 30 percent in 2015, 2020, and 2025 respectively (by International requirements). We assumed that the index would continue to require stricter efficiency requirements in 2040 and 2050, providing a 35 percent and 40 percent reduction in 2040 and 2050, respectively.

Improved Efficiency Requirements for New OGVs (Scenario 1)

Year	Increase in Efficiency (%)*	Deployment in New OGVs
2020	20	100
2030	30	100
2040	35	100
2050	40	100

*Same % reductions in NOx, PM2.5, ROG and CO_2

- Operational and Maintenance Best Practices:
  We estimated that fuel savings could be as high as 5 percent by using operational and maintenance best practices such as hull cleaning, “Just-in-Time” shipping operations, weather routing, and optimized navigation. We expect these fuel saving techniques will be adopted by more vessels over the next decades.

Operational and Maintenance Best Practices for New OGVs (Scenario 1)

Year	Increase in Efficiency (%)*	Deployment in New OGVs
2020	5	50
2030	5	70
2040	5	90
2050	5	100

*Same % reductions in NOx, PM2.5, ROG and CO_2

- Cleaner Diesel Fuel:
  Fuel sulfur levels continue to decline in distillate fuels. ARB staff expects this decline in sulfur to continue and for Scenario 2, assumed that eventually vessels will use an on-road grade diesel fuel. This will reduce PM2.5 emissions approximately 10 percent. Staff assumed 25 percent of new vessels to use on-road grade 15 ppm sulfur diesel fuel in 2020 increasing to 100 percent of vessels in 2050.

Cleaner Diesel Fuel for New OGVs (Scenario 1)

Year	PM2.5 Reductions (%)	Deployment in New OGVs
2020	10	25
2030	10	50
2040	10	75
2050	10	100

- LNG/Dual Fuel:
  Reductions of approximately 80 percent, 70 percent, and 10 percent of NOx, PM2.5, and CO_2, respectively can be achieved by using LNG relative to distillate fuels. Due to the lack of fueling infrastructure worldwide for LNG, for Scenario 2,

ARB staff estimated 5 percent of new vessels could use LNG in 2020 increasing to 20 percent in 2050.

LNG/Dual Fuel Vessels for New OGVs (Scenario 1)*

Year	NOx Reductions (%)	PM2.5 Reductions (%)	CO2 Reductions (%)	Deployment in New OGVs
2020	80	70	10	5
2030	80	70	10	10
2040	80	70	10	15
2050	80	70	10	20

*no increased efficiency or ROG reductions

Transiting-IN-USE OGVs

- Improved Efficiency Measures:
  For the in-use fleet, ARB staff assumed that vessels will increase the efficiency of their vessels. ARB staff assumed that about a 3 percent efficiency improvement with 50 percent of the vessels implementing improvements in 2020 increasing to 100 percent of the in-use fleet in 2050.

Improved Efficiency Measures for Transiting In-Use OGVs (Scenario 1)

Year	Increase in Efficiency (%)*	Deployment in In-Use OGVs
2020	3	50
2030	3	70
2040	3	90
2050	3	100

*correlates to reductions in NOx, PM2.5, ROG and CO2

- Operational and Maintenance Best Practices:
  The assumptions Operational and Maintenance Best Practices are the same as Transiting- New OGVs
- Cleaner Diesel Fuel:
  The assumptions for using cleaner diesel fuel are the same as Transiting- New OGVs
- Accelerated NOx Reductions:
  For in-use OGV, ARB staff assumed that there could be accelerated NOx benefits by either bringing more Tier III vessels or retrofitted vessels to California ports. ARB staff assumed that an additional 15 percent of the in-use vessels visiting California could meet this requirement.

Accelerated NOx Reductions for In-Use OGVs-Transiting (Scenario 1)

Year	NOx Reductions (%)	Deployment in In-Use OGVs
2020	75	15
2030	75	15
2040	75	15
2050	75	15

*reductions in NOx only

Hoteling-New and In-use OGVs

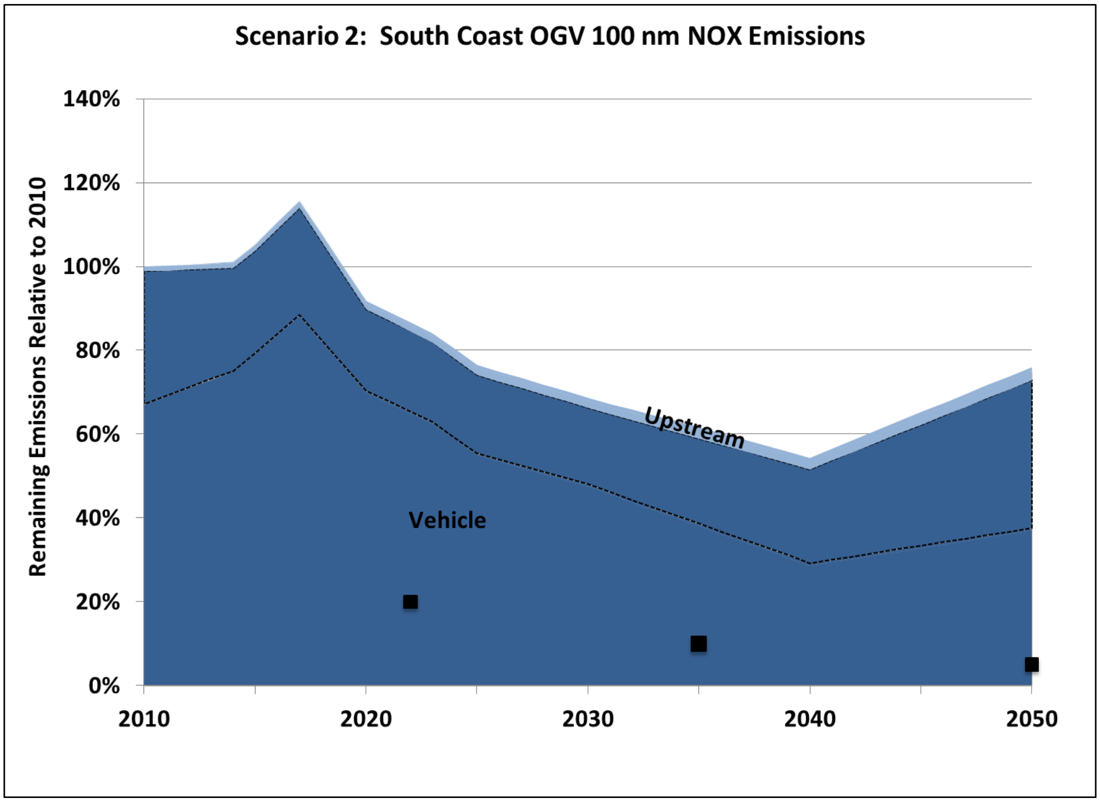
- Increased Shorepower:
  Shore power is already a requirement for vessels visiting California ports for container ships, refrigerated cargo ships, and passenger ship fleets. We assumed that there would be an increase in the number of vessels who take advantage of shore power while hoteling in California ports. It was assumed that by 2030, 75 percent of all OGVs would use shorepower, increasing to 80 percent by 2050. It was also assumed that the use of shorepower would result in a reduction of 80 percent in both NOx and PM2.5 emissions relative to an OGV using distillate fuels.

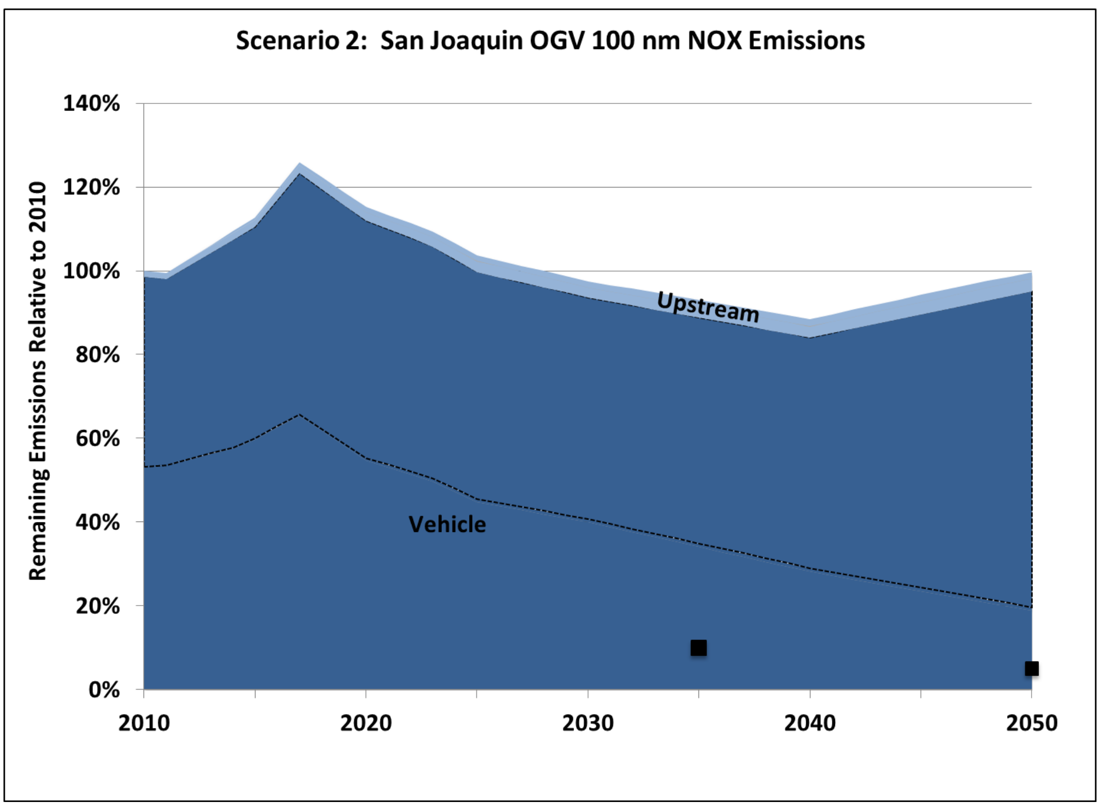
Shore Power or Equivalent Technology for New and In-use OGVs (Scenario 1)

Year	Increase in Efficiency (%)	NOx Reductions (%)	PM2.5 Reductions (%)	ROG Reductions (%)	CO2 Reductions (%)	Deployment in New & In-Use OGVs
2020	0	0	0	0	0	0
2030	0	80	80	80	80	75
2040	0	80	80	80	80	75
2050	0	80	80	80	80	80

Cleaner Diesel Fuel:

For those OGV not using shorepower, the assumptions for using cleaner diesel fuel are the same as those used for both Transiting In-use and Transiting-New Vessels.


Scenario 2: South Coast OGV 100 nm NOX Emissions
Remaining Emissions Relative to 2010
140%
120%
100%
80%
60%
40%
20%
0%
2010
2020
2030
2040
2050
Upstream
Vehicle


Scenario 2: San Joaquin OGV 100 nm NOX Emissions
Remaining Emissions Relative to 2010
140%
120%
100%
80%
60%
40%
20%
0%
2010
2020
2030
2040
2050
Upstream
Vehicle

<u>Scenario 3</u>: In Scenario 3, some, but not all, of the assumptions used to develop Scenario 2 were revised. The assumptions for LNG/Duel Fuel Vessels for New OGVs were more aggressive for Scenario 3. For the In-Use OGV-Transiting category, the assumptions for the Accelerated NOx Reductions were revised to be more aggressive in Scenario 3. For the New and In-use OGV Hoteling, the assumptions for Shore Power for New and In-use OGVs were more aggressive in Scenario 3.

Growth Rate

The growth rate was lowered from 5 percent in Scenario 2 to 3 percent in Scenario 3.

Transiting- New OGVs

- Improved Efficiency Requirements (EEDI):
  The assumptions for Improved Efficiency Requirements are the same as those used in Scenario 2.
- Operational and Maintenance Best Practices:
  The assumptions for Operational and Maintenance Best Practices are the same as those used in Scenario 2.
- Cleaner Diesel Fuel:
  The assumptions for Improved Efficiency Requirements are the same as those used in Scenario 2.
- LNG/Dual Fuel:
  In Scenario 3, we assumed a more aggressive rate of deployment in new vessels with 40 percent of new vessels being LNG fueled by 2015. In both Scenario 2 and Scenario 3, we used the same reductions for NOx, PM2.5, and CO2.

LNG/Dual Fuel Vessels for New OGVs (Scenario 2)

Year	Increase in Efficiency (%)	NOx Reductions (%)	PM2.5 Reductions (%)	ROG Reductions (%)	CO2 Reductions (%)	Deployment in New OGVs
2020	0	80	70	0	10	10
2030	0	80	70	0	10	20
2040	0	80	70	0	10	30
2050	0	80	70	0	10	40

Transiting-In USE OGVs

- Improved Efficiency Measures:
  The assumptions for Improved Efficiency Requirements are the same as those used in Scenario 2.
- Operational and Maintenance Best Practices:
  The assumptions for Operational and Maintenance Best Practices are the same as those used in Scenario 2.
- Cleaner Diesel Fuel:
  The assumptions for Improved Efficiency Requirements are the same as those used in Scenario 2.
- Accelerated NOx Reductions:

In Scenario 3, we assumed that there would be more aggressive accelerated NOx benefits. We assumed that an additional 30 percent of the vessels visiting California would meet the more stringent Tier III NOx standards.

Accelerated NOx Schedule for In-Use Vessels (Scenario 2)

Year	NOx Reductions (%)*	PM2.5 Reductions (%)	Deployment for In-use Vessels
2020	75	0	30
2030	75	0	30
2040	75	0	30
2050	75	0	30

*Reductions in NOx only

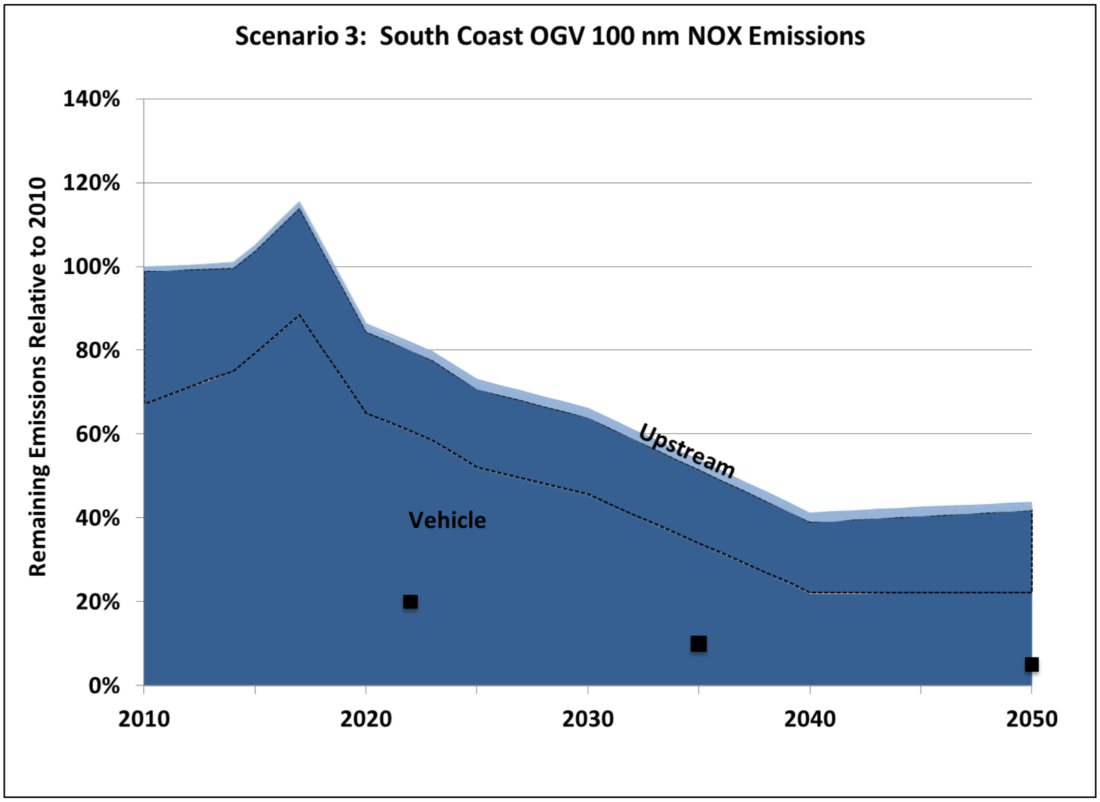
Hoteling-New and In-use OGVs

- Increased Shorepower:
  In Scenario 3, we assumed that the increase in the number of new vessels that take advantage of shore power would be even greater than in Scenario 2. We increased the maximum deployment to 100 percent in 2050 and also increased the deployment in 2040 to 85 percent of new vessels. We used the same reduction control factor as was used in Scenario 2.

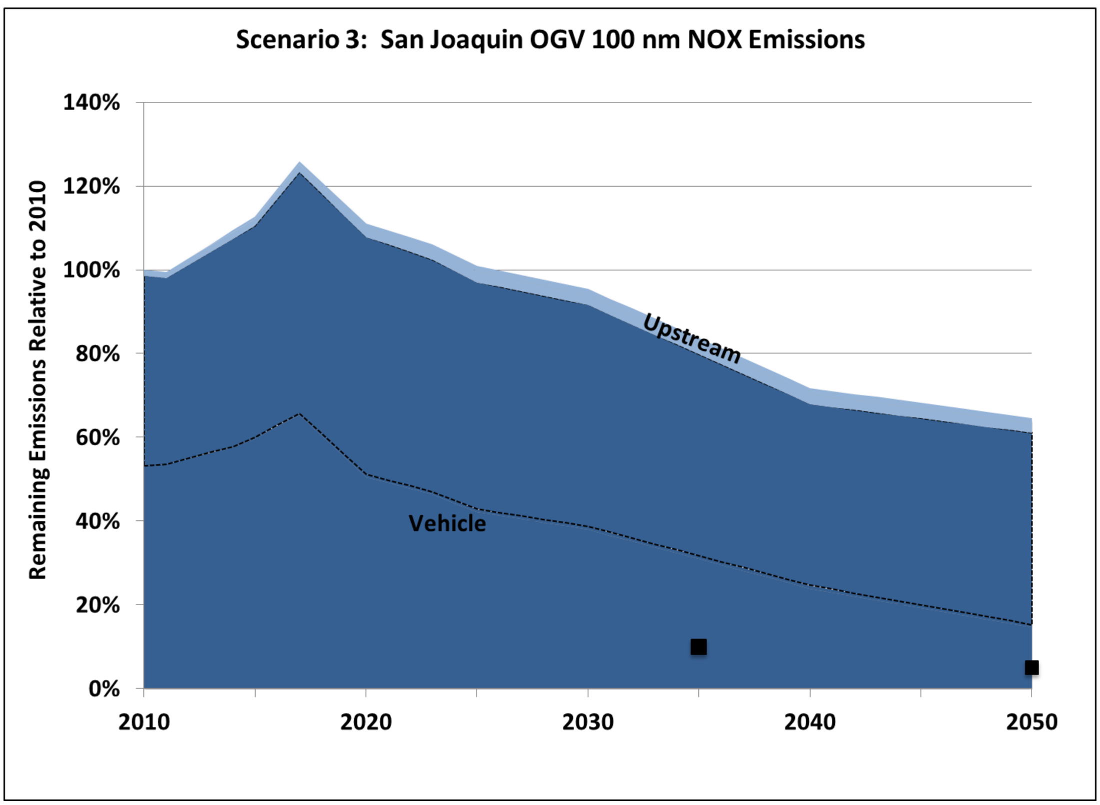
Shore Power for New and In-use Vessels (Scenario 2)

Year	Increase in Efficiency (%)	NOx Reductions (%)	PM2.5 Reductions (%)	ROG Reductions (%)	CO2 Reductions (%)	Deployment in New Vessels
2020	0	0	0	0	0	0
2030	0	80	80	80	80	75
2040	0	80	80	80	80	85
2050	0	80	80	80	80	100

- Cleaner Diesel Fuel:
  The assumptions for cleaner diesel fuel are the same as those used in Scenario 2.



Scenario 3: South Coast OGV 100 nm NOX Emissions
Remaining Emissions Relative to 2010
140%
120%
100%
80%
60%
40%
20%
0%
2010
2020
2030
2040
2050
Upstream
Vehicle

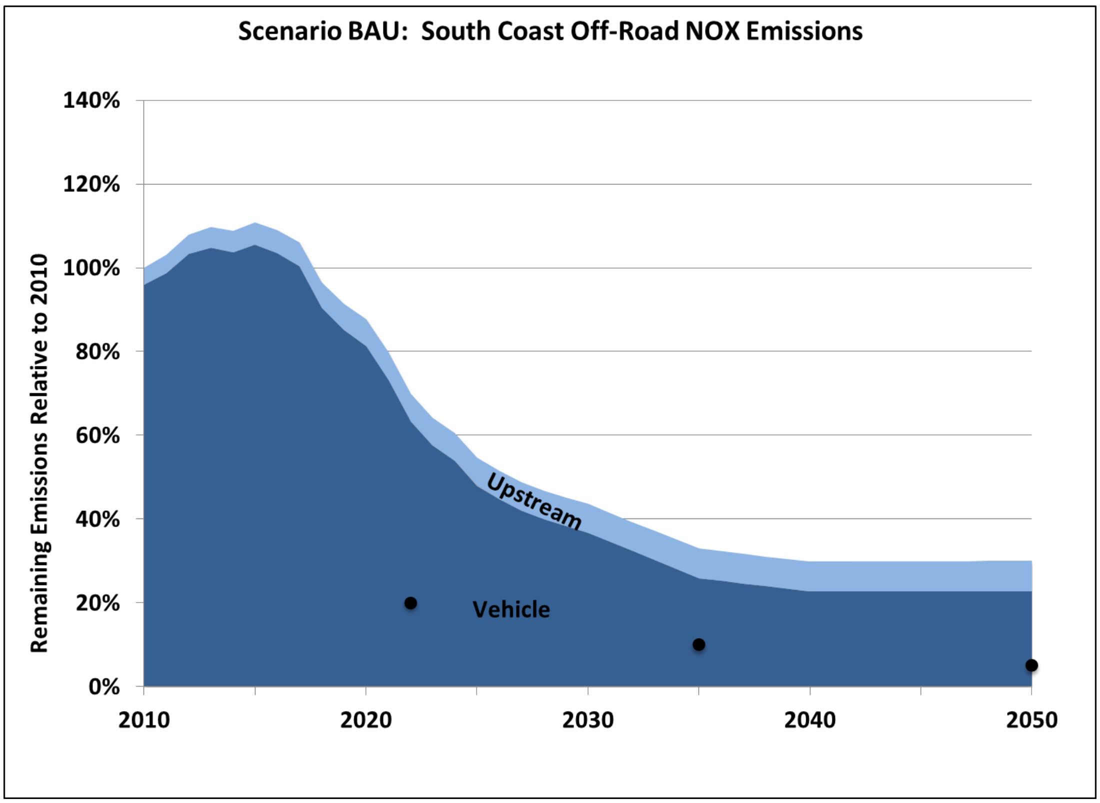


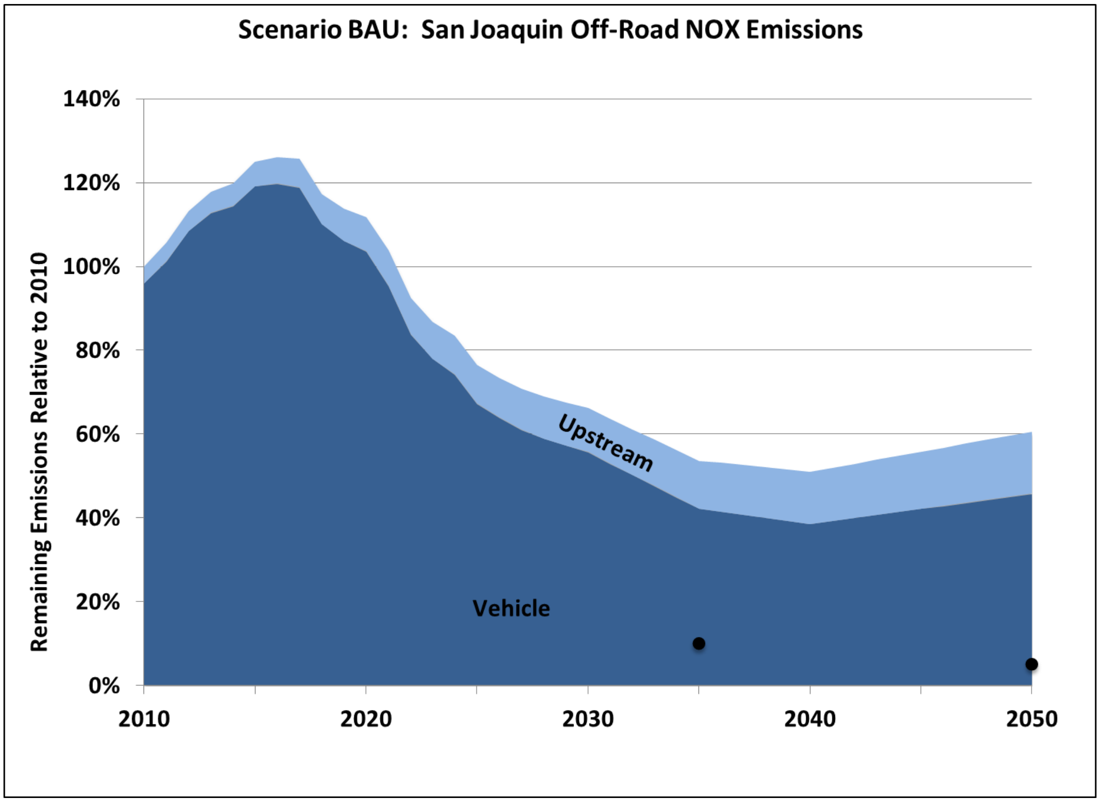
Scenario 3: San Joaquin OGV 100 nm NOX Emissions
Remaining Emissions Relative to 2010
140%
120%
100%
80%
60%
40%
20%
0%
2010
2020
2030
2040
2050
Upstream
Vehicle

Off-Road Vehicles

For each of the sectors staff developed a set of assumptions for each scenario. In general, the three scenarios used for off-road vehicles are described below.

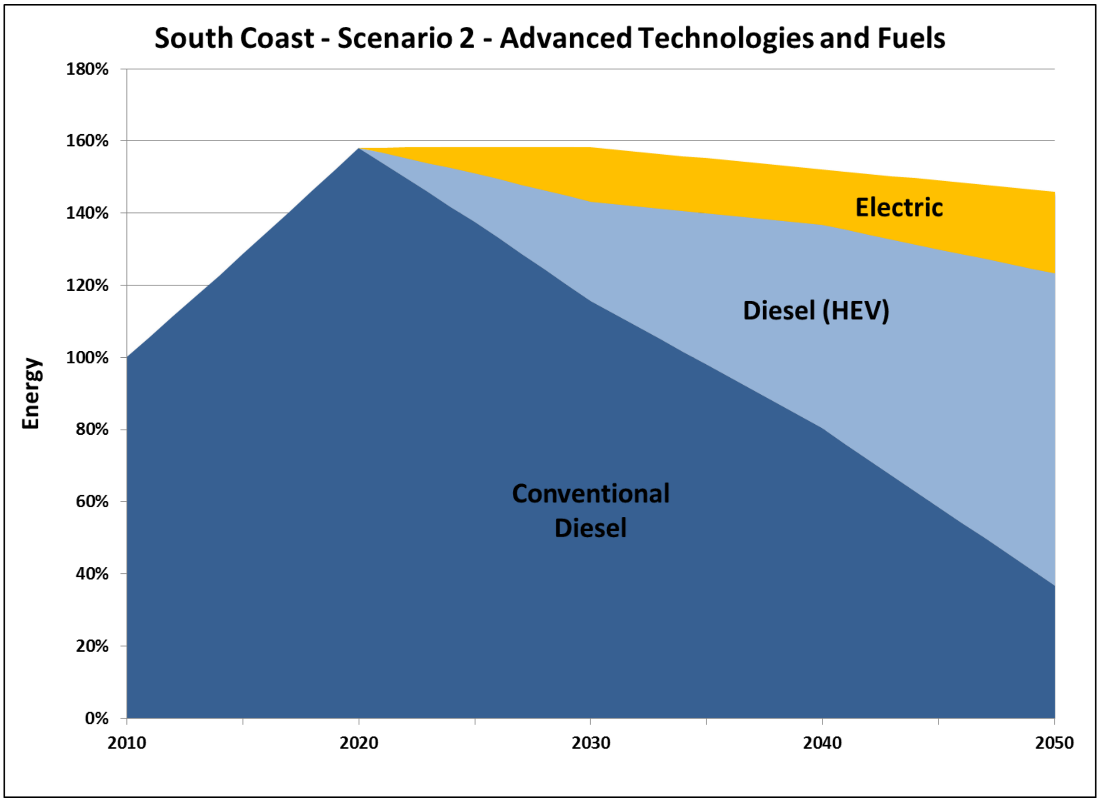
<u>Scenario 1</u>: This scenario represents business as usual. It includes all current federal and state programs, including adopted regulations that will be implemented in the future, such as the Regulation for In-Use Off-Road Diesel Fueled Fleets (Off-Road regulation, begins implementation in 2014), and the Tier 4 (final) standards that will be phased in 2013 to 2015.

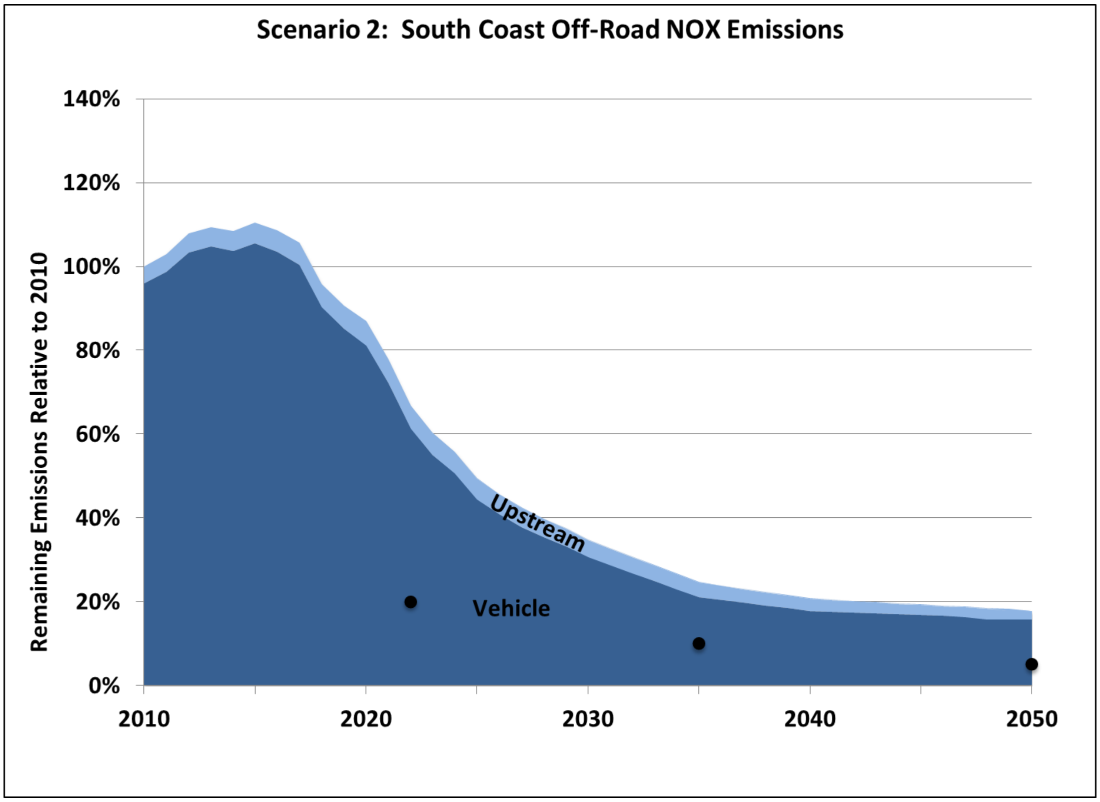


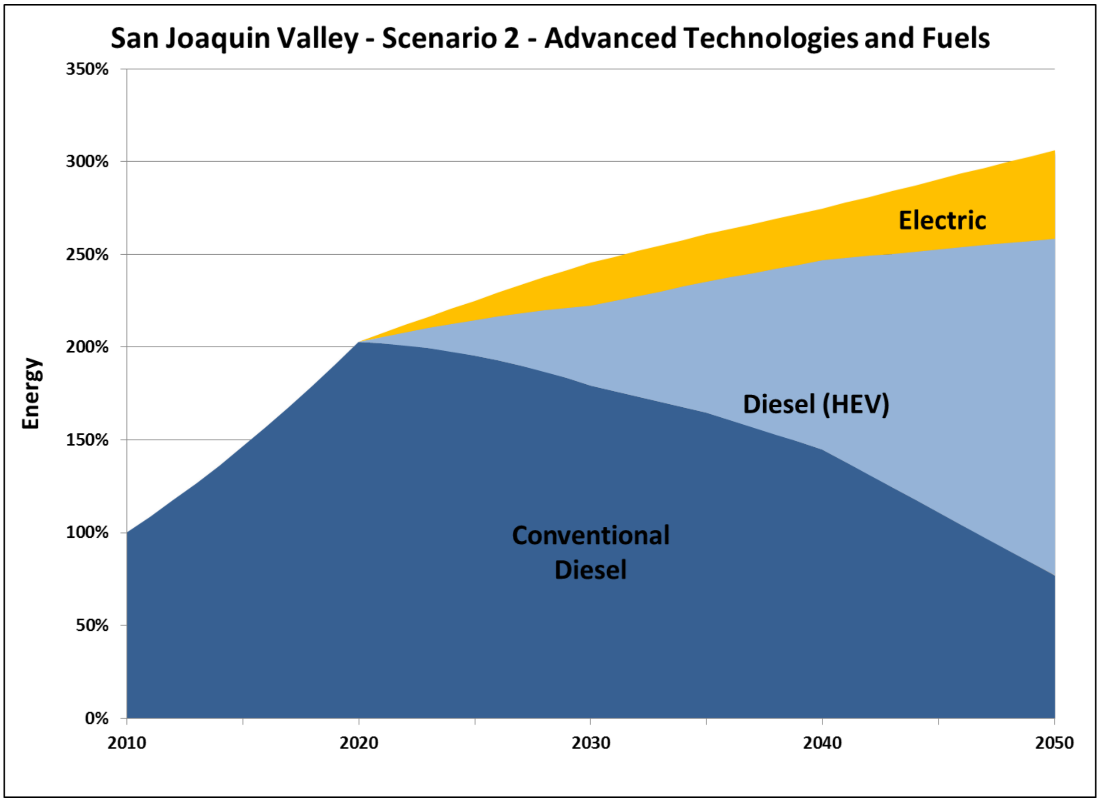


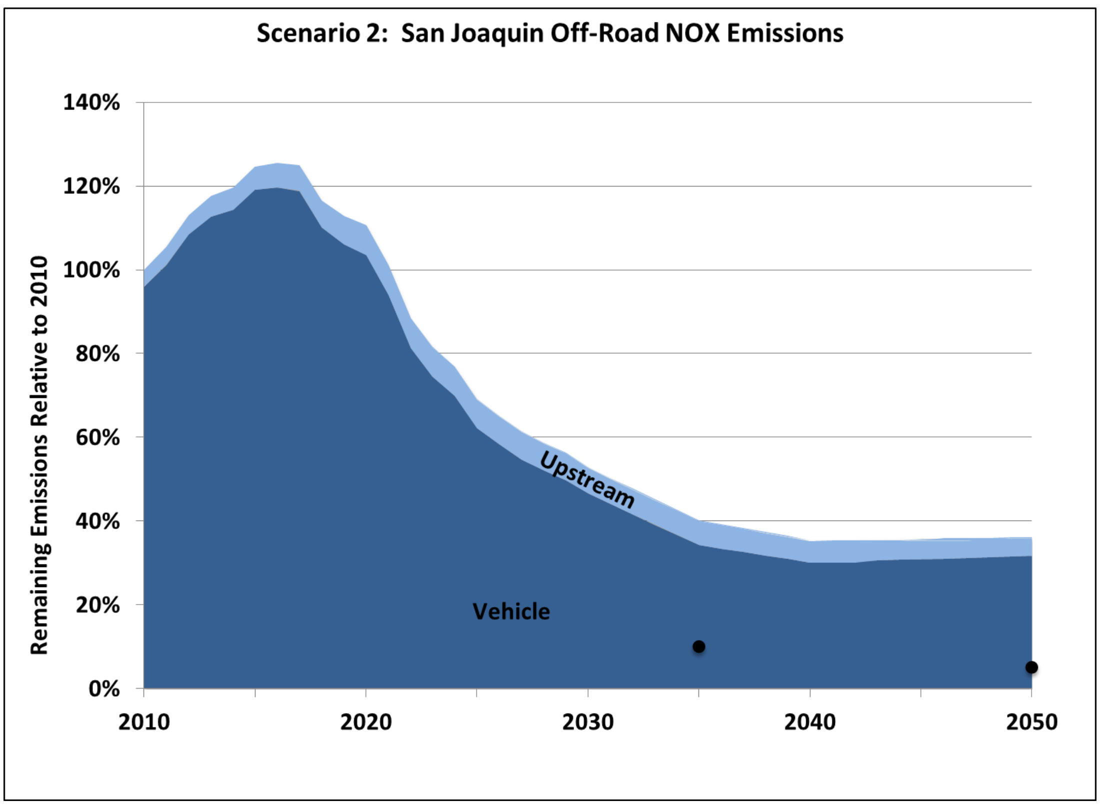
Scenario 2: This scenario builds on scenario 1 by including a phased transition to cleaner technologies. The scenario assumes:

- A linear phase-in of zero emitting (electric of fuel cell) and hybrid technologies beginning in 2025. By 2050, approximately 15 percent of off-road equipment would need to be zero emitting, and approximately 65 percent would need to utilize hybrid technology.
- The approximately 20 percent of the fleet utilizing conventionally fueled vehicles would need to use vehicles cleaner and more efficient than those meeting the current Tier 4 standards. A linear phase-in of this new standard (NOx 60 percent lower than Tier 4 levels) would begin in 2025 and was assumed to apply to new vehicles through natural turnover.


South Coast - Scenario 2 - Advanced Technologies and Fuels
Energy
180%
160%
140%
120%
100%
80%
60%
40%
20%
0%
2010
2020
2030
2040
2050
Electric
Diesel (HEV)
Conventional Diesel

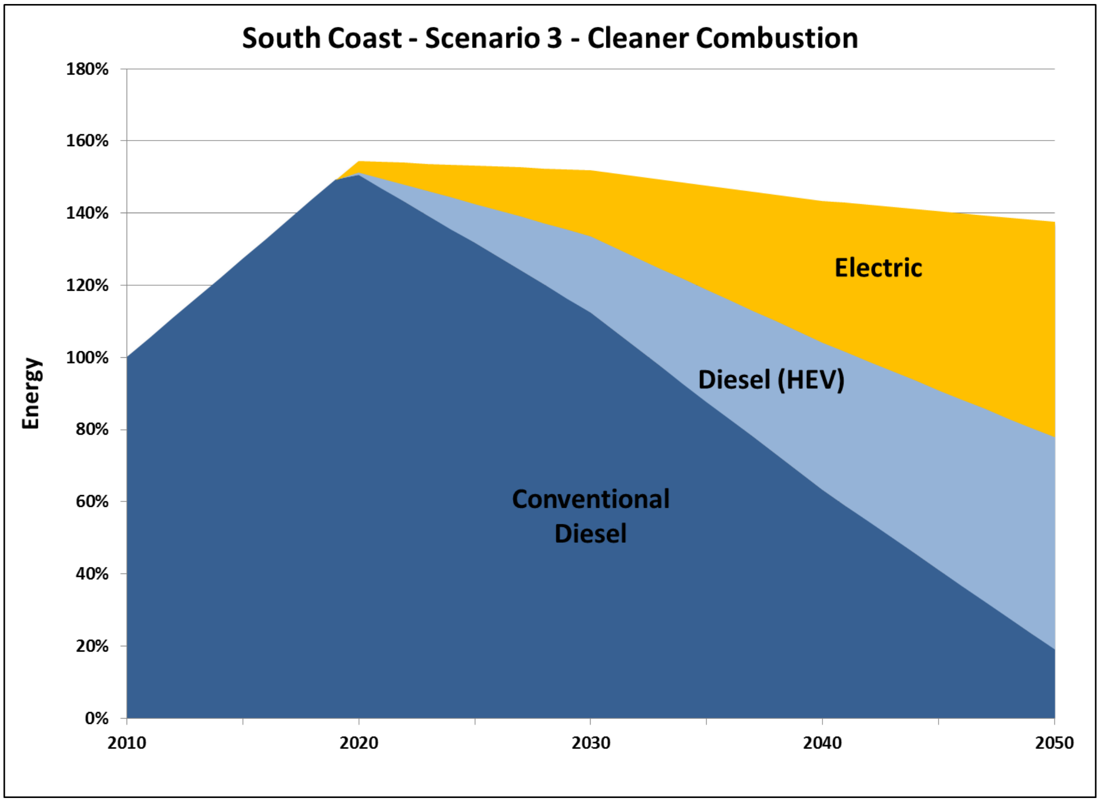

Scenario 2: South Coast Off-Road NOX Emissions
Remaining Emissions Relative to 2010
140%
120%
100%
80%
60%
40%
20%
0%
2010
2020
2030
2040
2050
Upstream
Vehicle

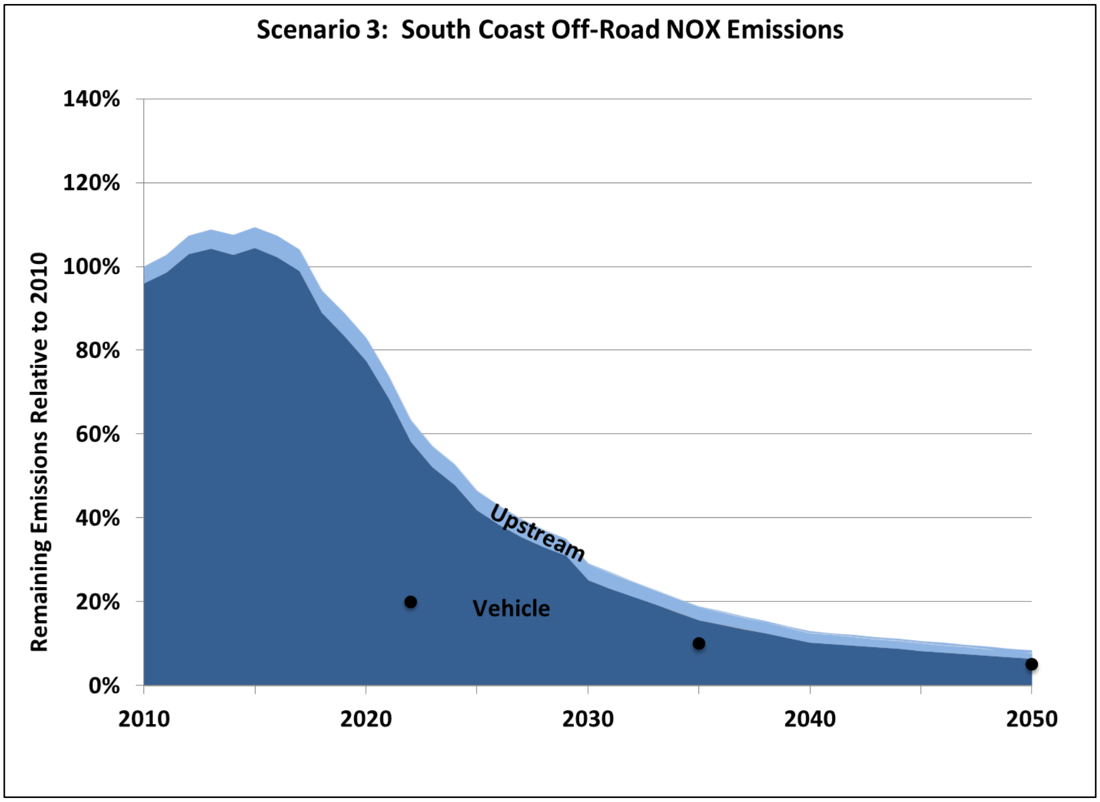

San Joaquin Valley - Scenario 2 - Advanced Technologies and Fuels
Energy
350%
300%
250%
200%
150%
100%
50%
0%
2010
2020
2030
2040
2050
Electric
Diesel (HEV)
Conventional Diesel

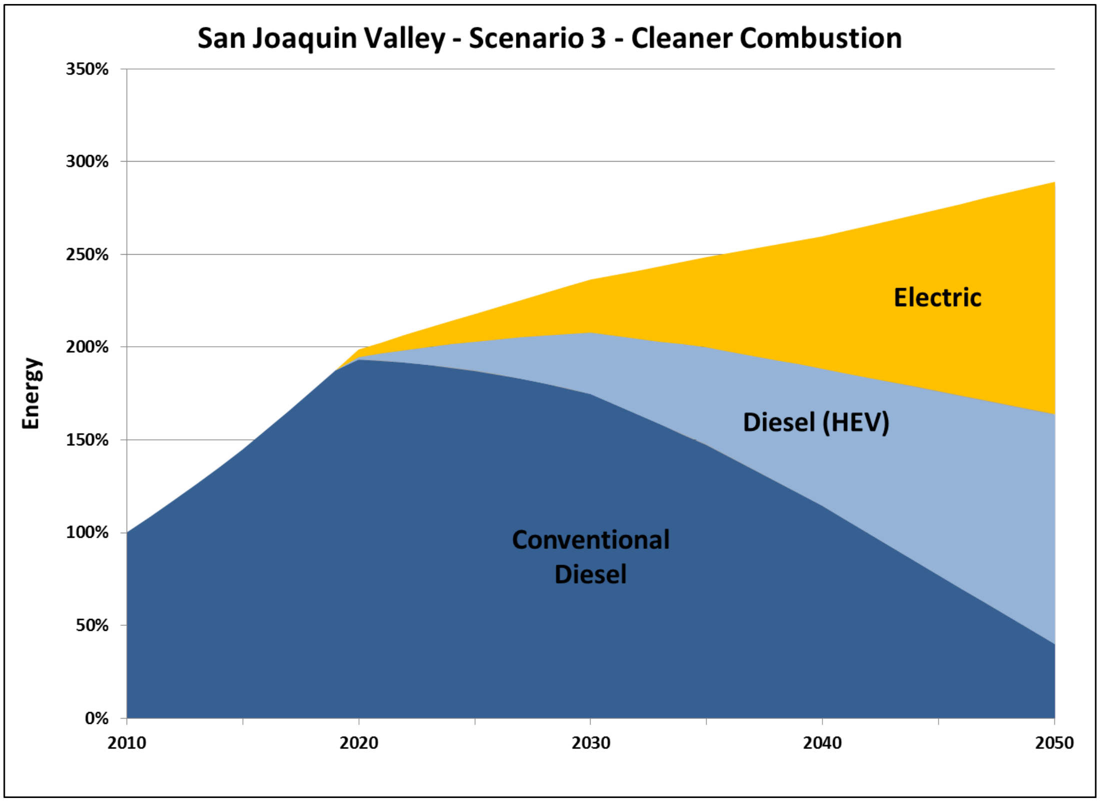

Scenario 2: San Joaquin Off-Road NOX Emissions
Remaining Emissions Relative to 2010
140%
120%
100%
80%
60%
40%
20%
0%
2010
2020
2030
2040
2050
Upstream
Vehicle

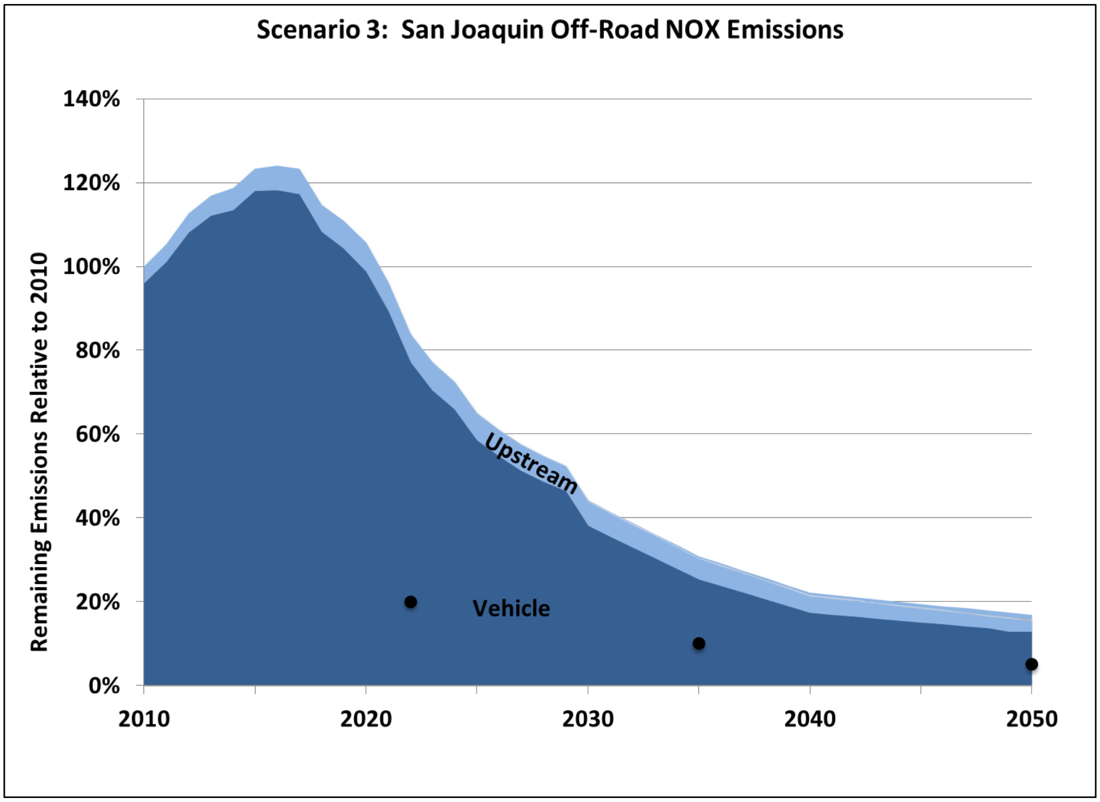
Scenario 3: This scenario builds on scenarios 1 and 2, and represents a more aggressive integration of advanced technologies and cleaner fuels. The scenario assumes:

- Beginning in 2020, a more aggressive linear phase in of zero emitting and hybrid vehicles. By 2050, approximately 40 percent of off-road equipment would need to be zero emitting and approximately half would need to utilize hybrid technology.
- Beginning in 2025, the remaining 10 percent would need to utilize conventionally fueled vehicles cleaner and more efficient than those meeting the current Tier 4 standards.




Scenario 3: South Coast Off-Road NOX Emissions
Remaining Emissions Relative to 2010
140%
120%
100%
80%
60%
40%
20%
0%
2010
2020
2030
2040
2050
Upstream
Vehicle


San Joaquin Valley - Scenario 3 - Cleaner Combustion
Energy
350%
300%
250%
200%
150%
100%
50%
0%
2010
2020
2030
2040
2050
Electric
Diesel (HEV)
Conventional Diesel

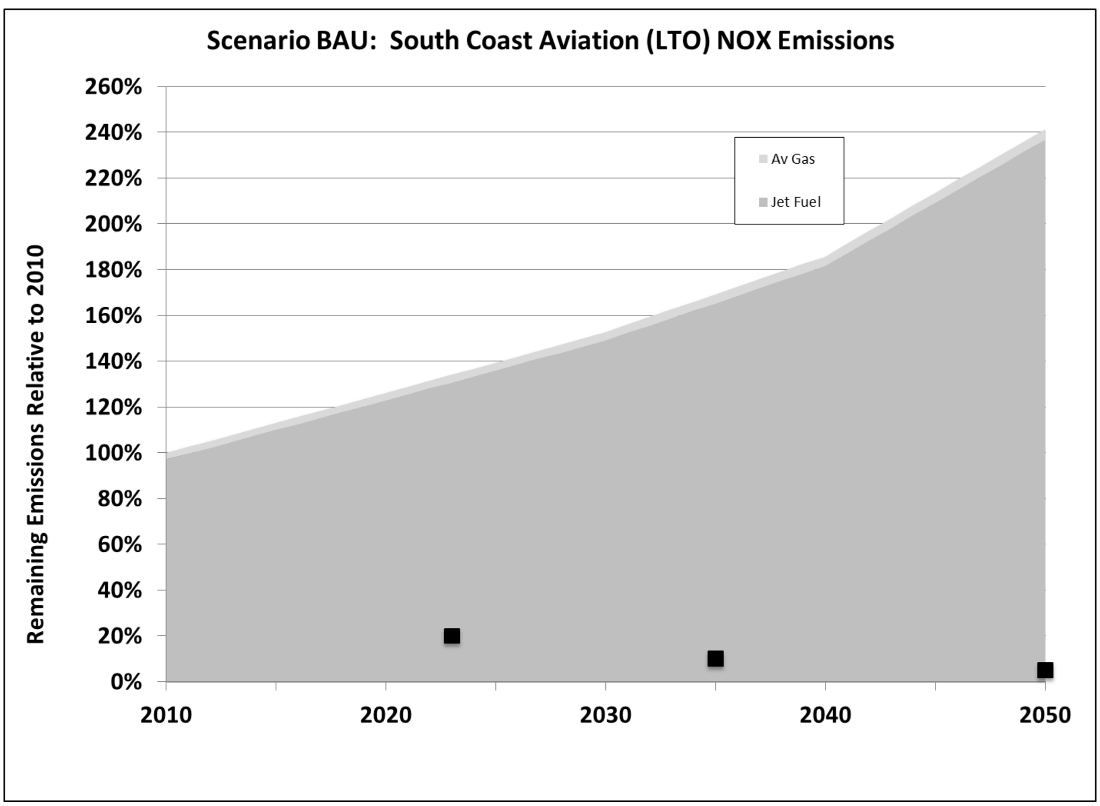

Scenario 3: San Joaquin Off-Road NOX Emissions
Remaining Emissions Relative to 2010
140%
120%
100%
80%
60%
40%
20%
0%
2010
2020
2030
2040
2050
Upstream
Vehicle

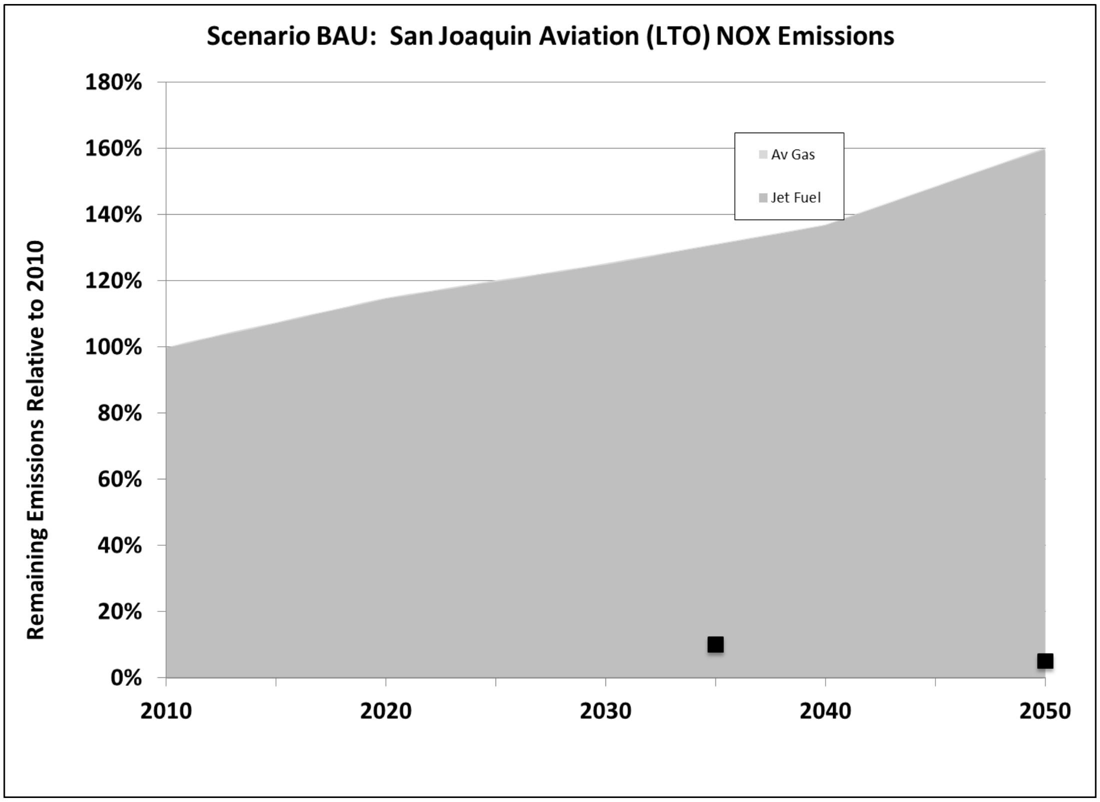
Aviation

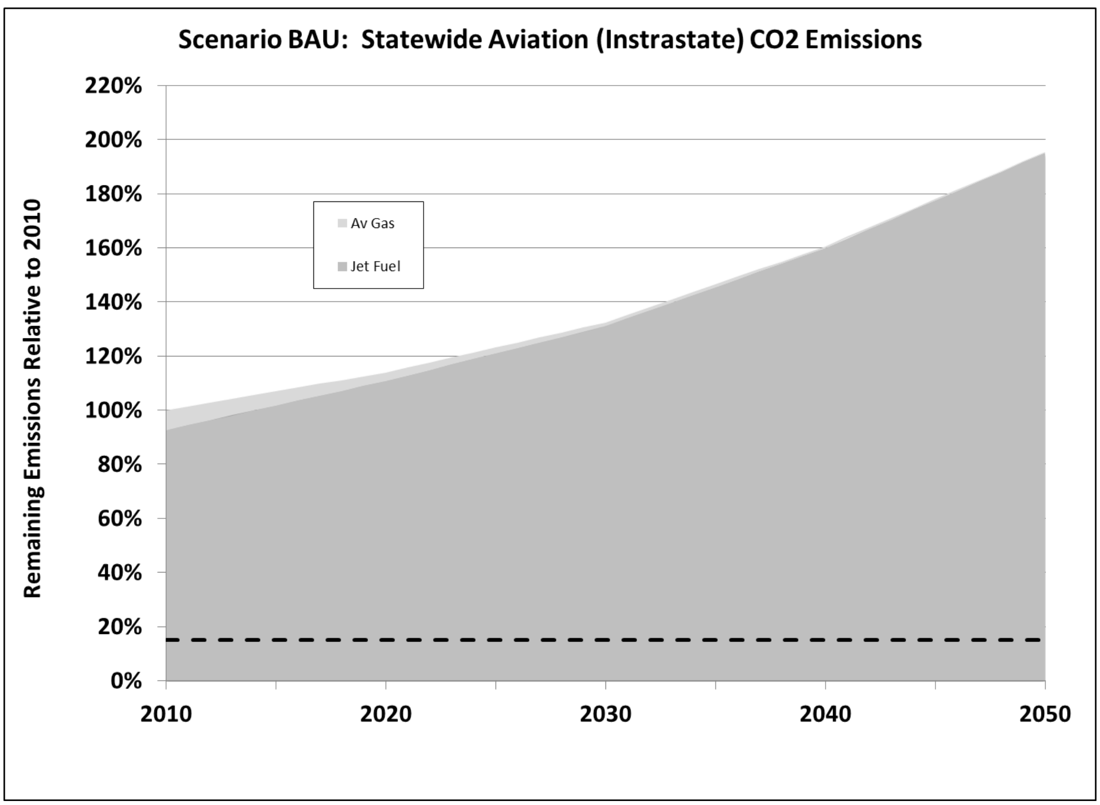
Staff efforts for this analysis have focused primarily on the subset of the sector using jet fuel, since over 90 percent of aircraft emissions are from this subset. This means that the impacts in the San Joaquin Valley are substantially lower than those in the South Coast, or even statewide.

For the last several decades, the total growth in passenger miles and cargo miles has been on the order of five to six percent per year. Aviation emissions have not grown as quickly due to historical improvements in operational efficiencies and aircraft technology that result in a net emissions growth of one to two percent per year.

Scenario 1: The BAU scenario uses the current emission estimates and applies a constant annual growth rate of 1.5 percent. The lead federal agency for this sector, U.S. EPA, has adopted a range of criteria pollutant standards over the past few years in conjunction with the International Civil Aviation Organization's (ICAO) Committee on Aviation Environmental Protection (CAEP); it is reasonable to assume that they will continue to act to reduce emissions using future standards. The currently proposed Tier 6 (or CAEP/6) and the Tier 8 (or CAEP/8) standards are included in this scenario.




Scenario BAU: San Joaquin Aviation (LTO) NOX Emissions
Remaining Emissions Relative to 2010
180%
160%
140%
120%
100%
80%
60%
40%
20%
0%
2010
2020
2030
2040
2050
Av Gas
Jet Fuel


Scenario BAU: Statewide Aviation (Instrastate) CO2 Emissions
Remaining Emissions Relative to 2010
220%
200%
180%
160%
140%
120%
100%
80%
60%
40%
20%
0%
2010
2020
2030
2040
2050
Av Gas
Jet Fuel

Scenario 2: The second scenario represents the best efforts of the federal agencies responsible for control of these sources. These published goals were utilized to generate the second scenario.

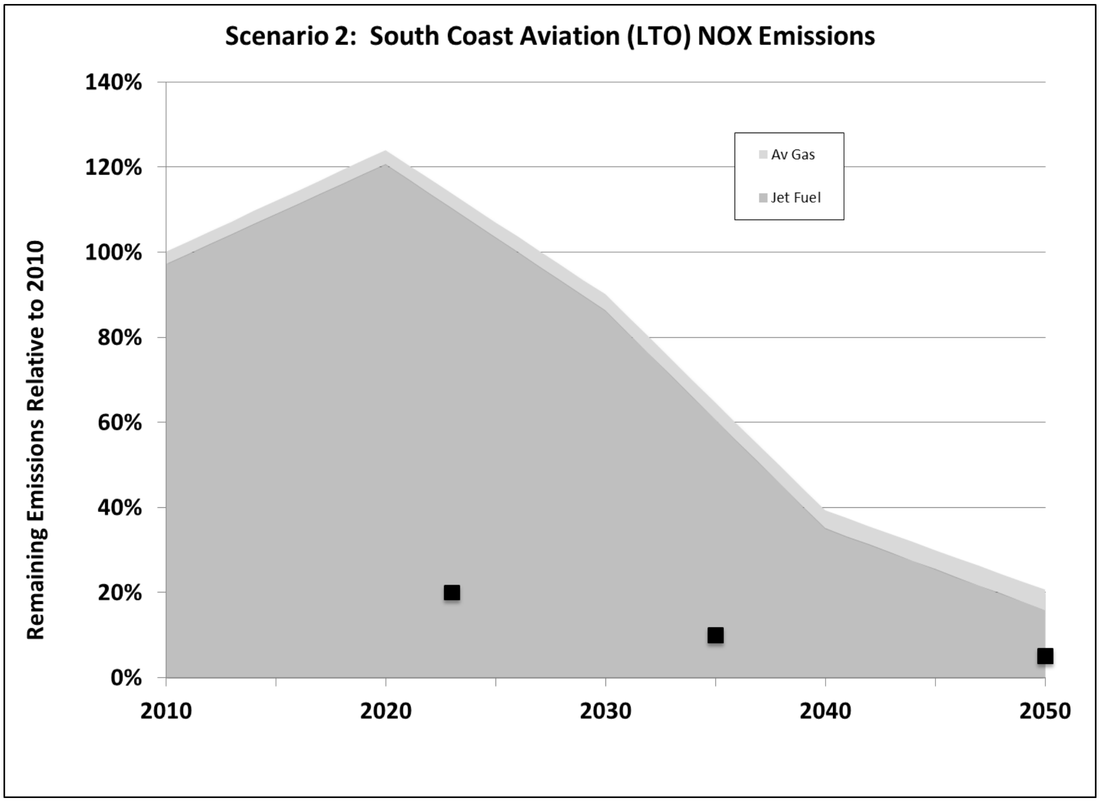
Staff assumed introduction of Tier 6 / Tier 8 as in the BAU Scenario. Also included are expected improvements in operational efficiencies based on the NextGen navigation and airspace utilization improvements currently being developed and promulgated by the Federal Aviation Administration (FAA).

In addition, the Federal Aviation Administration has recently launched the Continuous Lower Energy, Emissions, and Noise (CLEEN) program. The precise technologies have yet to be identified, but NOx and greenhouse gas reductions on the order of 75 percent in about model year 2030 are targeted. The FAA has entered into research agreements with five manufacturers for $125 million with an equal match required of the participants in an effort to meet the goals outlined in the table below.

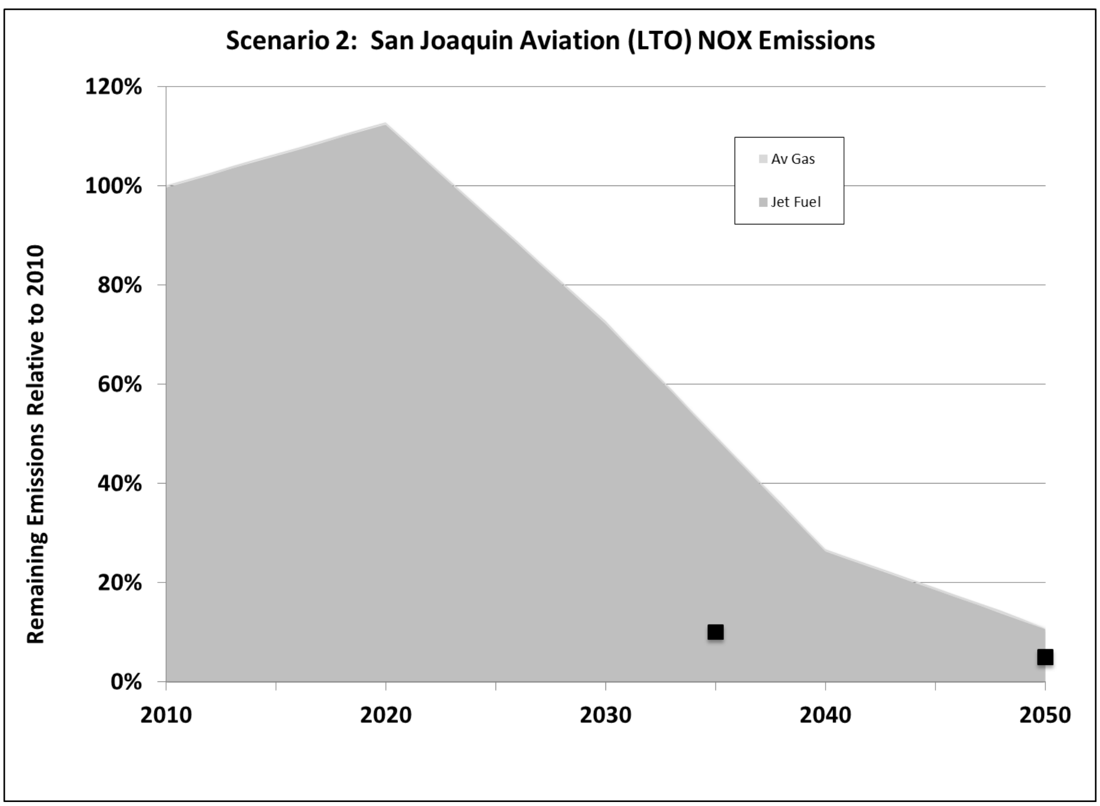
Emissions and Fuel Reduction Goals for FAA CLEEN Program			
	(2015-2018)	(2020-2025)	(2030-2035)
LTO NOx Emissions (below CAEP 6)	-60 %	-75 %	> -75 %
Aircraft Fuel Burn	-33 %	-50 %	> -70 %

The following assumptions were used to integrate the FAA's CLEEN program goals into the model scenario:

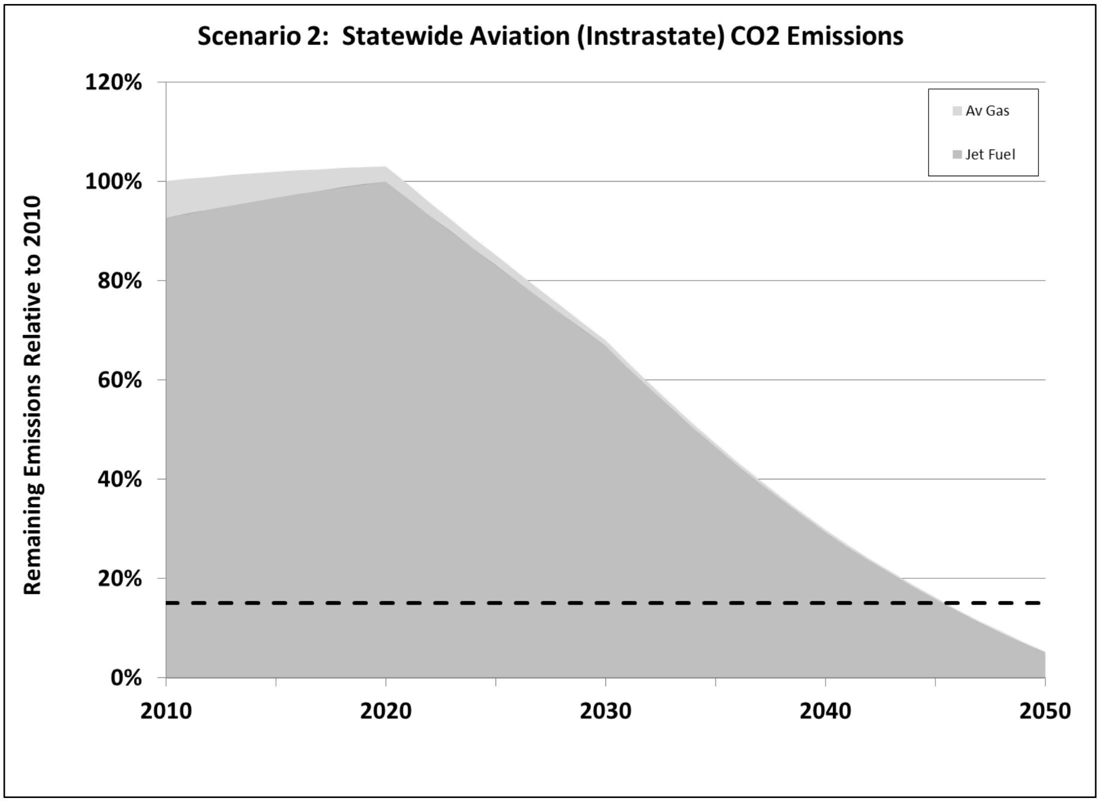
- Goals above are standards that must be met for new aircraft in the applicable years shown.
- Year of introduction is average where range is given (i.e. 2022.5 for 2020-2025).
- Aircraft life is 25 years.
- Assumed an additional five percent where goal is 'greater than' (i.e. 80 percent for > 75 percent).
- Reductions apply to all non-military aircraft using jet fuel (does not apply to aircraft using avgas).



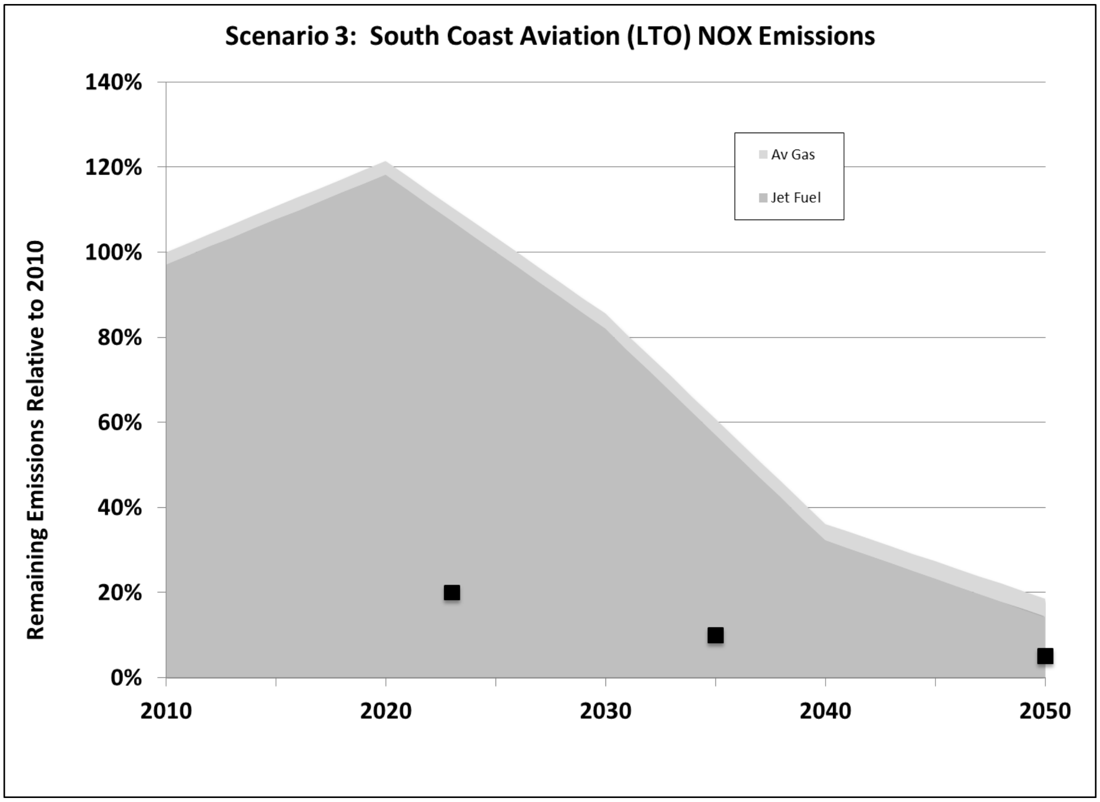
Scenario 2: South Coast Aviation (LTO) NOX Emissions
140%
120%
100%
80%
60%
40%
20%
0%
Remaining Emissions Relative to 2010
2010
2020
2030
2040
2050
Av Gas
Jet Fuel

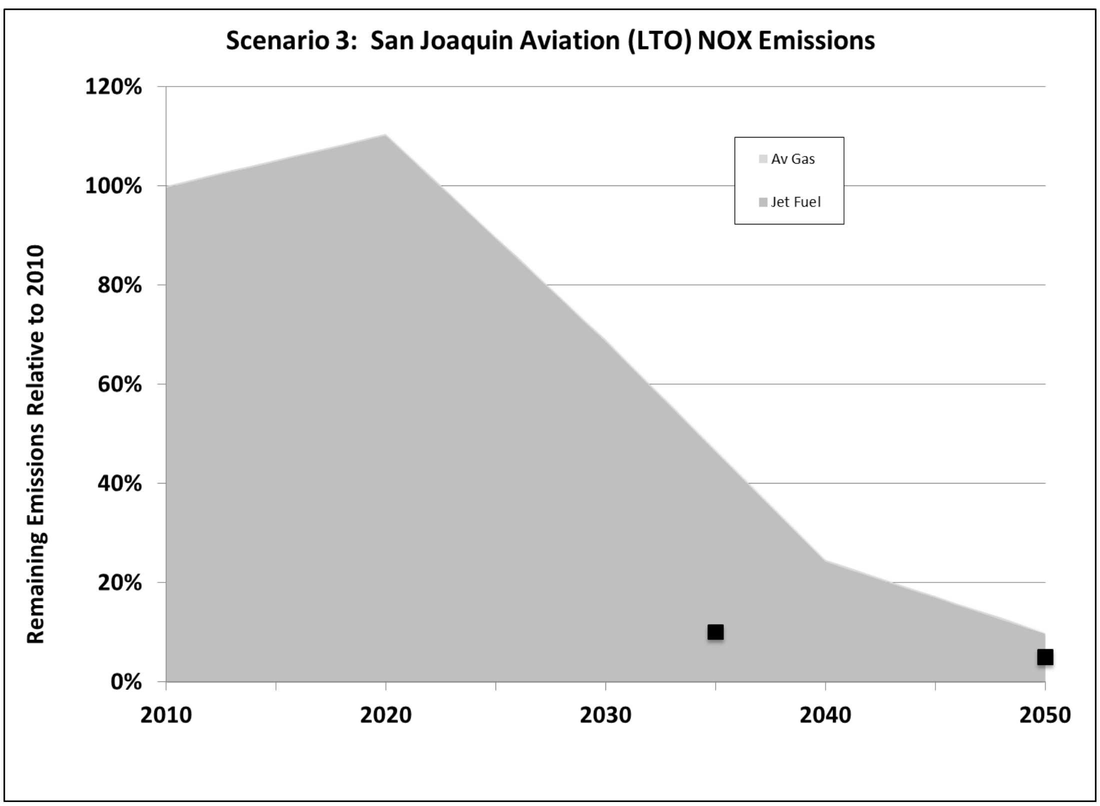


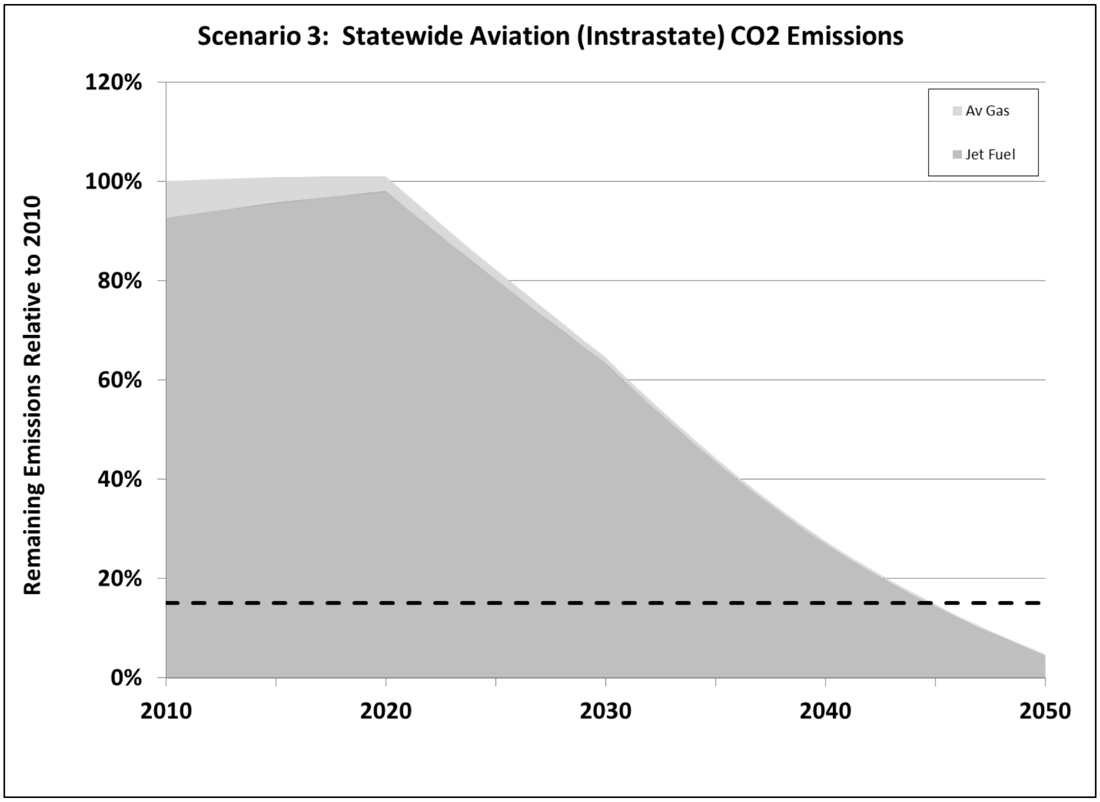
Scenario 2: San Joaquin Aviation (LTO) NOX Emissions
120%
100%
80%
60%
40%
20%
0%
Remaining Emissions Relative to 2010
2010
2020
2030
2040
2050
Av Gas
Jet Fuel



Scenario 3: The third scenario is identical to the second scenario except for the additional assumption of a ten percent reduction in activity by 2050.


Scenario 3: South Coast Aviation (LTO) NOX Emissions
Remaining Emissions Relative to 2010
140%
120%
100%
80%
60%
40%
20%
0%
2010
2020
2030
2040
2050
Av Gas
Jet Fuel


Scenario 3: San Joaquin Aviation (LTO) NOX Emissions
Remaining Emissions Relative to 2010
120%
100%
80%
60%
40%
20%
0%
2010
2020
2030
2040
2050
Av Gas
Jet Fuel


Scenario 3: Statewide Aviation (Instrastate) CO2 Emissions
Remaining Emissions Relative to 2010
120%
100%
80%
60%
40%
20%
0%
2010
2020
2030
2040
2050
Av Gas
Jet Fuel

Energy

For the Vision scenarios, fuel supply choices were derived from the various mobile sectors after reviewing the technical feasibility of certain alternative fuels in various applications. However, the upstream emissions characteristics and feedstock choices (sources of energy) were derived independently of the end-using sector. For example, renewable diesel was chosen based on the anticipated demand from on-road trucks in the future, but the choice of which biomass crops and which refining process were not dependent on the vehicles consuming it. In general, various energy sources were reviewed for each type of fuel, and where physical supplies were reasonable, the energy source with the lowest upstream emission profile was chosen.

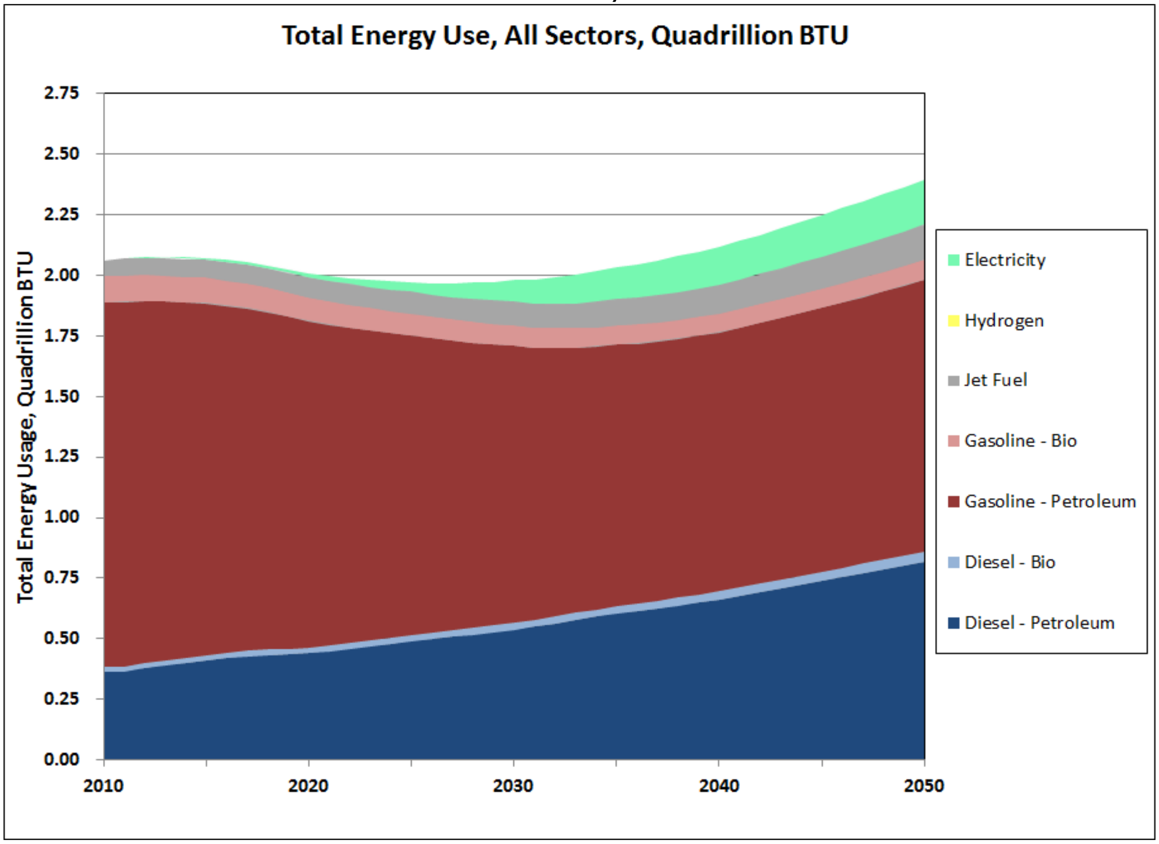
Total fuel demand was derived from the consuming mobile sectors in the scenarios, based on vehicle population, in-use efficiencies, and projected activity. In a few select cases, energy supply constraints were applied to the analysis. For the future electricity grid, the supply of nuclear power and large hydroelectricity were constrained to today's supply capacity levels in California.

Scenario 1: The BAU scenario reflects the programs and regulations that are currently in place and fully implemented as well as adopted standards and regulations with future implementation dates. Specific to the energy sector, this includes the State's Renewable Portfolio Standard, the Low Carbon Fuel Standard, AB 32, and SB 1505 (renewable hydrogen production requirement).

Several specific assumptions were made for the BAU scenario, including:

- Fixed fuel carbon intensity values from 2025 to 2050 even as vehicle population grows
- 10 percent ethanol blend in gasoline, although total ethanol volumes increase with use of E85 in some flex fuel vehicles.
- Electricity grid production mix fixed at a 2020 projection with 33 percent renewables
- For conventional liquid fuels, all fuel upstream criteria emissions were assumed to be included in the air basin for each case. This includes resource well extraction, fuel production and delivery.

Scenario 1 BAU, Statewide:

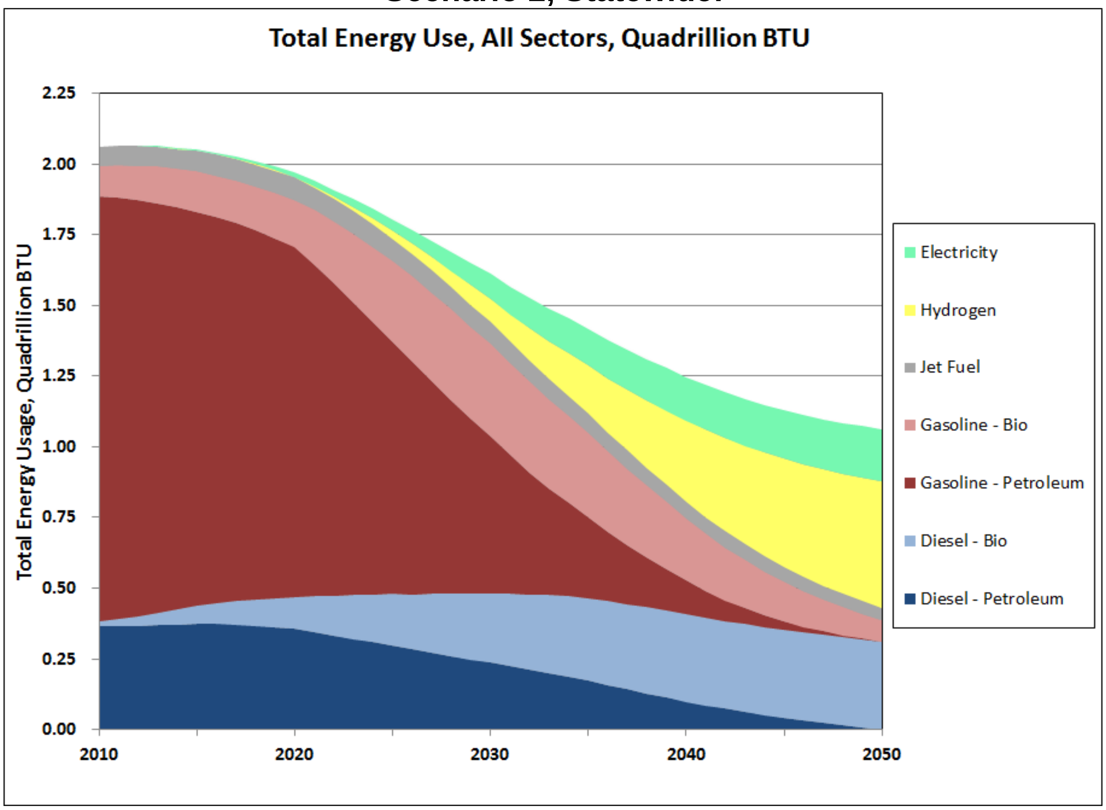


Scenario 2:
This scenario goes well beyond the Scenario 1 by adding the following:

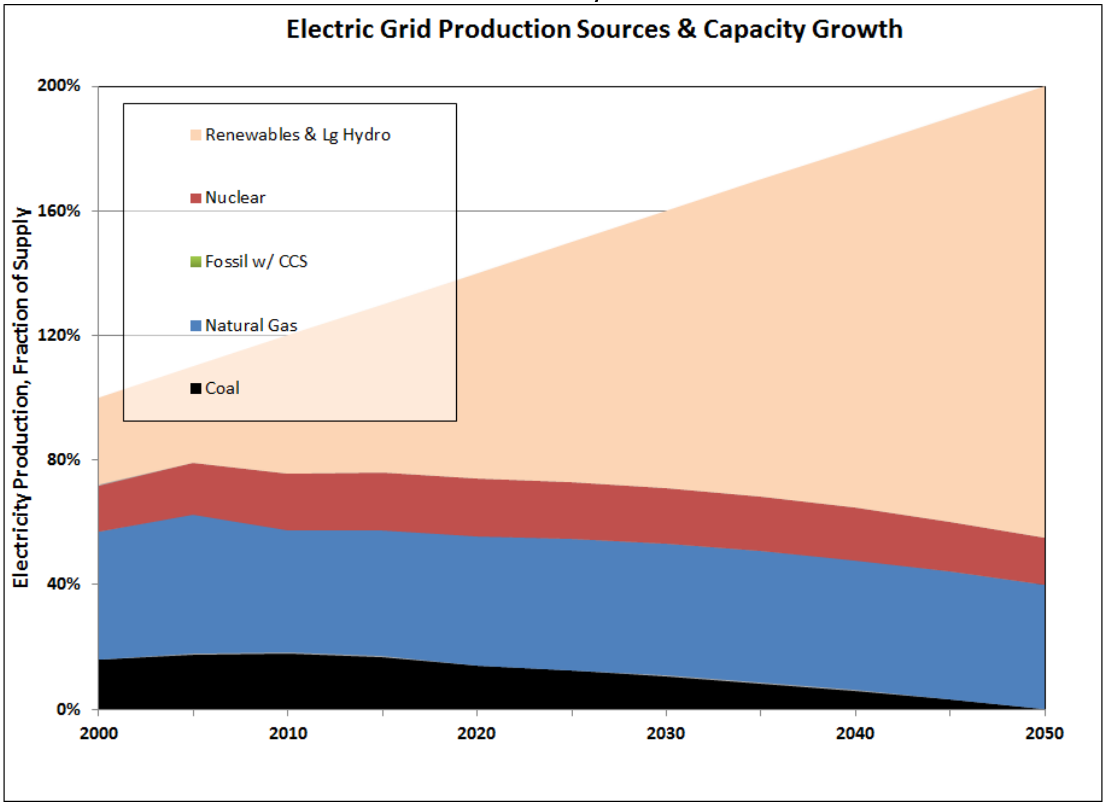
- Gasoline fuel with blending alternatives
    - By 2020, ethanol is blended in at 15 percent (higher blend wall)
    - By 2020, 25 percent of the flex fuel vehicles were assumed to consume E85
    - Renewable gasoline enters the market around 2020, slowly phasing out ethanol and increasing blend ratios with conventional gasoline to 2050
- Diesel fuel with blending alternatives
    - Biodiesel has a fixed blend ratio of 5 percent for all years
    - Renewable diesel enters the market around 2020, with increasing blend ratios up to 2050
- A biomass resource limit of 6 billion gallons of gasoline equivalent (BGGE) was assumed for the California market
    - Transition to low-carbon advanced biomass feedstocks over time
- Renewable jet fuel enters the market around 2020, with increasing blend ratios up to 2050
- Two future electricity grid production mix cases were for created. By 2050:
    - High renewables case: ~65 percent renewables and ~8 percent large hydro supply

    - Carbon Capture and Storage (CCS) case: ~20 percent CCS in 2050 with less renewables and less natural gas power production (without CCS)
- For hydrogen, a balanced mix was chosen given the uncertainty in any one technology's commercialization status. The scenario mix included wind-based electrolysis, low-carbon biomass, and CCS with either coal or natural gas.
- For all alternative fuels, half of the fuel upstream criteria emissions were included in the air basin for each case.

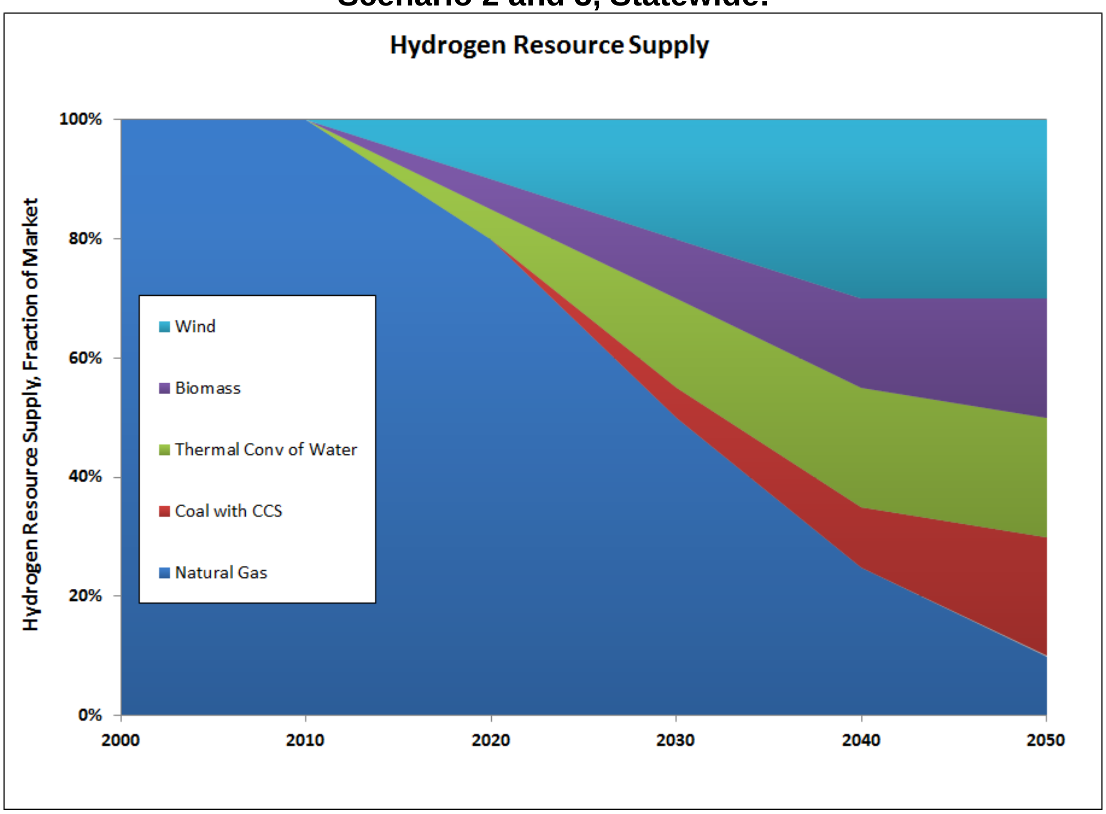
Scenario 2, Statewide:



Scenario 2 and 3, Statewide:



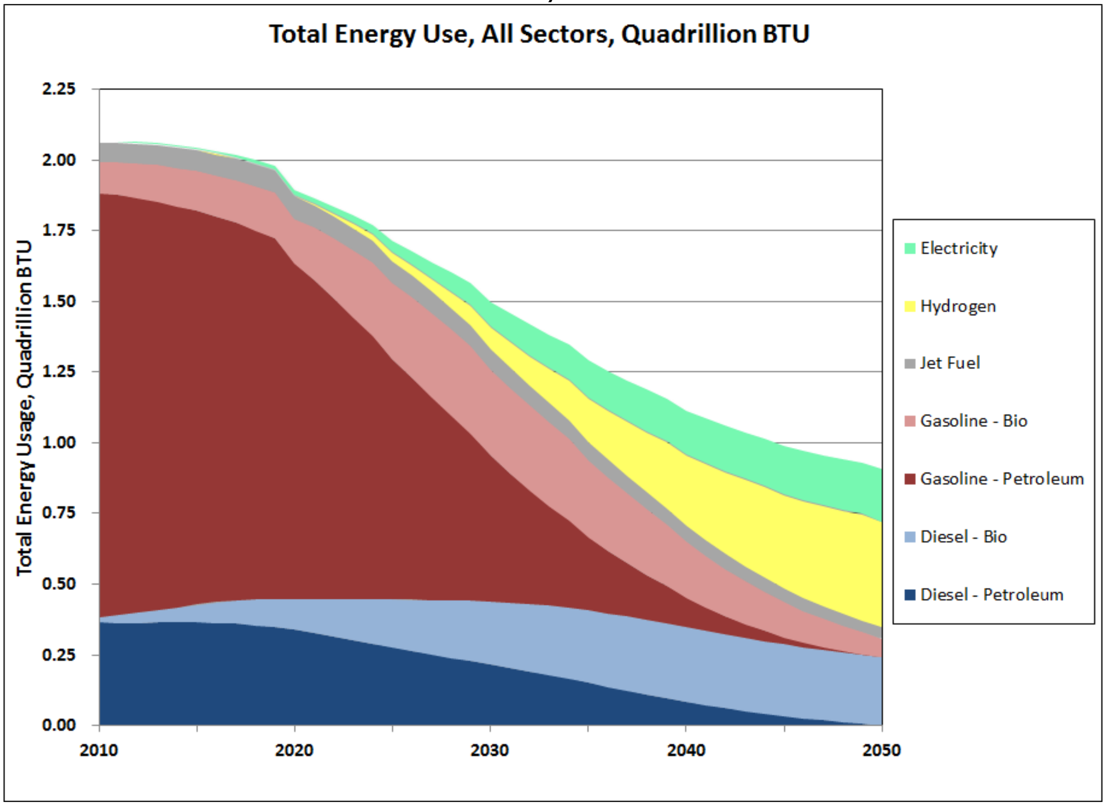
Scenario 2 and 3, Statewide:



Scenario 3:

For the energy sector, no additional changes were made to the assumptions for Scenario 3.

Scenario 3, Statewide:



Scenario 3, Statewide: